GREEN BOOK

FOR

THE LONG-TERM GROUNDWATER

MANAGEMENT PLAN FOR

THE OWENS VALLEY AND INYO COUNTY

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PREPARED BY

<u>INYO COUNTY</u>

GREG JAMES
  WATER DIRECTOR
DR. DAVID GROENEVELD
  PLANT ECOLOGIST
BILL HUTCHISON
  HYDROLOGIST

<u>CITY OF LOS ANGELES</u>

DENNIS C. WILLIAMS
  ENGINEER IN CHARGE,
  LOS ANGELES AQUEDUCT DIVISION
RUSSELL H. RAWSON
  ENGINEER,
  LAND & RESOURCES MANAGEMENT
EUGENE L. COUFAL
  HYDROLOGIC ENGINEER

The Agreement between the County of Inyo and the City of
Los Angeles and its Department of Water and Power on a Long-term
Groundwater Management Plan for the Owens Valley and Inyo County
(Agreement) in Section I.E provides:

> "The location of each management area, vegeta-
> tion monitoring site, and each monitoring
> well; the wells linked to each vegetation
> monitoring site; the method for locating addi-
> tional monitoring sites and monitoring wells;
> the type of monitoring to be conducted at
> each site; and the standardized procedures
> for analysis and interpretation of monitoring
> results, including the determination of avail-
> able soil water and the amount of soil water
> required by vegetation, are set forth in a
> technical document called a 'Green Book.'
> This 'Green Book' will be attached as a
> technical appendix to the final long-term
> Agreement and its accompanying environmental
> impact report (EIR)."

This document is the "Green Book."

The Green Book consists of five primary sections. The sections
are:

    I.   Vegetation Management
   II.   Vegetation Inventory and Development of
        Vegetation Management Maps
  III.   Vegetation Monitoring
   IV.   Hydrologic Management
    V.   Further Studies

Section I on Vegetation Management describes the goals and
principles of the Agreement that pertain to management of the

vegetation types. This section sets forth the procedures and methods for achieving these goals and principles.

Section II describes the process of compiling the vegetation inventories and the development of the management maps that are to be used in achieving the goals of the Agreement.

Section III describes the techniques and methods to monitor the vegetation and calculate soil-plant water requirements.

Section IV outlines the criteria and procedures to be used in monitoring and evaluating hydrologic data. Also, the section sets forth the procedures for locating and operating the new wells, and the methods of avoiding groundwater mining.

Section V of the Green Book outlines further studies that are being considered to more effectively achieve the goals and principles of the Agreement over the long term or needed to refine monitoring procedures based on new technology.

Section VI, the Appendix, contains various supporting technical vegetation information.

Provisions for revising and updating the Green Book are specified in Section III.E of the Agreement, which states:

> ". . . modifying the provisions of the 'Green Book' as a result of information gained from ongoing research and cooperative studies or for other reasons, as may be necessary to improve the effectiveness of the monitoring and the evaluation activities."

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I. VEGETATION MANAGEMENT

This Green Book section describes methods for achieving the goals and principles for vegetation management of the Agreement. Unless otherwise specified, determinations, decisions, or actions called for in this section will be made by the Technical Group. When reference is made to changes in surface water management practices, changes will be determined in comparison with past practices since 1970.

A. Management Goals

The overall goal of managing the water resources within Inyo County is to avoid certain described decreases and changes in vegetation and to cause no significant effect on the environment which cannot be acceptably mitigated while providing a reliable supply of water for export to Los Angeles and for use in Inyo County. This means that groundwater pumping and changes in surface water management practices will be managed with the goal of avoiding significant decreases and changes in Owens Valley vegetation from conditions documented in 1984 to 1987, and of avoiding other significant environmental impacts.

For management purposes, the Agreement divides the vegetation of the Owens Valley floor into five management types classified as A, B, C, D, and E. Should it be determined through ongoing monitoring, studies, or analysis, that vegetation is incorrectly classified, it will be reclassified as appropriate. The management goals for Owens Valley vegetation are:

1. Type A Vegetation

    This type, composed of vegetation with a calculated
    ET rate approximately equal to precipitation,
    should not be affected by groundwater pumping or by
    changes in surface water management practices since
    such vegetation survives on available precipitation.

2. Types B, C, and D Vegetation

    The goal is to manage groundwater pumping and
    surface water management practices so as to avoid
    causing significant decreases in live vegetation
    cover, and to avoid causing a significant amount of
    vegetation now comprising either the Type B, C, or
    D classification to change to vegetation in a
    classification type that precedes it alphabetically
    (for example, Type D changing to either C, B, or A
    vegetation). In addition, a general goal is to not
    convert Type D vegetation to cultivated agriculture.

3. Type E Vegetation (lands supplied with water)

    These lands will be supplied with water and will be
    managed to avoid causing significant decreases and
    changes in vegetation from vegetation conditions
    that existed on such lands during the 1981/82 run-
    off year. Also, water will be supplied in an
    amount sufficient so that the water-related uses of
    such lands that were made during the 1981/82 runoff
    year can continue. However, the conversion of
    cultivated land by the Department or its lessee to
    other irrigated uses shall not be considered a
    significant decrease or change. Another primary
    goal is to avoid significant decreases in

recreational uses and wildlife habitats that in the past have been dependent upon water supplied by the Department.

B. <u>Vegetation Monitoring and Management Practices</u>

One means of achieving the management goals for Owens Valley vegetation is an extensive monitoring program developed with the intent of identifying water management-caused problems before impacts occur. Since Owens Valley vegetation varies in its water consumption and sensitivity to soil water changes, different approaches for vegetation monitoring have been tailored to the five vegetation management types. The monitoring procedures are described in detail in Section III.

1. Type A Vegetation

Vegetation of Type A shall, in general, not receive intensive ground measurements, but will be monitored by remote sensing, visual, and other appropriate means.

2. Types B and C Vegetation

Vegetation of management Types B and C generally will be monitored using the procedures for projecting soil-to-plant water balance. Since the species constituting management Types B and C are relatively drought hardy, constant water table/root zone contact is not required for their survival.

a. Groundwater Management

Monitoring within existing well fields will occur at permanently established sites that are

linked to pumping wells. Projections of the balance between plant water requirements and soil water availability shall be made to determine whether groundwater pumping may continue or whether pumping should be discontinued. The soil water monitoring sites have been chosen to provide advance warning of plant water deficit in the area of influence from the linked wells. Each monitoring site shall be selected to reflect the combination of dominant vegetation, soil type, or other relevant factors within a management area.

i. Selection of Monitoring Sites and Linkage of These Sites to Wells - Types B and C

Within existing well fields, each well will be tied to a permanent monitoring site. These monitoring sites have been established to permit projecting soil-to-plant water balance, using the monitoring techniques described in Section III and the well turn-on and turn-off provisions described below.

o All existing production wells are currently tied to monitoring sites except wells which are exempt from well turn-off and turn-on provisions, as set forth in Section I.B.2.a.ii.

o For nonexempt wells, monitoring sites have been and will be selected following completion of a hydrologic

site assessment described in Section IV. Such hydrologic analyses will be used to determine what land areas lie within the potential zone of influence from either individual wells or well fields. The following activities shall be performed to locate a monitoring site after the hydrologic analyses have been completed:

- Vegetation and management area maps will be reviewed to determine location and area of vegetation cover that has the potential of being adversely impacted by ground-water pumping.

- If the vegetation is B or C, soil maps of the region surrounding each pumping well (available from U.S. Soil Conservation Service mapping efforts) will be examined to determine the location and extent of soil types. Vegetation monitoring sites shall then be established to represent the appropriate vegetation type, soil (especially water-holding capacity), topography, and other related factors.

o Each pumping well will be tied to a monitoring site established for projecting soil-to-plant water balance

for Types B and C. Table I.A lists
the current monitoring sites and the
pumping wells to which they are
linked.

TABLE 1.A

WELLFIELD MONITORING SITES & CONTROL SITES

MONITORING SITE	YEAR ESTABLISHED	MONITORING WELL	ASSOCIATED PUMPING WELLS	ASSOCIATED E/M WELL
Wellfields				
Laws:				
L1	1987	795T	246,247,248,249	
L2	1987	USGS 1	236,239,243,244,365	
L3	1990 *		240,241,242	376,377
L4a,4b	1989	2 Piezometers		385,386
L5	#		245	387,388
Bishop Cone:				
B1	#		137,138,140,141, 238,235,207,371	
Big Pine:				
BP1	1989	798T	210,352	378,379,389
BP2	1987	799T	220,229,374	375
BP3	1987	567T	222,223,231,232	
BP4	1989	800T	331	
Taboose/Aberdeen:				
TA3	1987	505T	106,110,111,114	
TA4	1989	586T	342,347	
TA5	1989	801T	349	
TA6	1989	803T	109,370	
Thibaut/Sawmill:				
TS1	1987	807T	159	
TS2	1988	806T	155	
TS3	1988	454T	103,104	382
TS4	1989	804T		380,381
Independence/Oak:				
IO1	1987	809T	77,391	
IO2	1987	548T	63	
IO3	#		61,59,65,57,60	383,384
Symmes/Shepherd:				
SS1	1987	USGS 9G	69,392,393	
SS2	1987	646T	74,394,395	
SS3	1987	561T	92,396	99
SS4	1987	811T	75,345	
Bairs/Georges:				
BG2	1989 **	812T	76,95,343,348	

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MONITORING SITE	YEAR ESTABLISHED	MONITORING WELL	ASSOCIATED PUMPING WELLS	ASSOCIATED E/M WELL
Control Sites				
Bishop:				
BC1	1988	USGS 2A "I"		
BC2	1989	796T		
BC3	1989	797T		
Taboose/Aberdeen:				
TAC	1989	802T		
Thibaut/Sawmill:				
TSC1 ∅	1989	805T		
Independence:				
IC1	1987	USGS 8 "D"		
IC2	1989	801T		

* Established in 1989, but moved in 1990
\# No vegetation monitoring site currently established
** Established in 1987, but moved in 1989
∅ Formerly TS5

- Vegetation monitoring sites that may experience adverse impacts due to the drawdown of the water table during pumping will be tied to production well(s) with the greatest hydrologic connection (based on such factors as groundwater flow and pumping patterns) and potential for impacting the water table at the monitoring site.

- If hydrologic conditions change such that the linkage of production well(s) to a monitoring site should be changed, the Technical Group may establish new monitoring sites and may redesignate the linkage between wells and monitoring sites as appropriate.

- An existing monitoring site may be
  relocated if a problem develops
  with the site, or if the results
  are inconsistent or of question-
  able nature, and if relocation is
  agreed to by the Technical Group.
  In the event of monitoring site
  relocation, measurements will be
  conducted at both the initial and
  the new sites for a maximum of one
  year, if possible, unless such
  monitoring is not required by the
  Technical Group. If a monitoring
  site is relocated, the criteria
  discussed above will be used to
  select the new site.

ii. Well Turn-on and Turn-off Provisions

Wells will be turned off and turned on
as one of the primary methods of
achieving the goals of the Agreement.
Wells that are not required to be turned
off under the provisions below may be
turned off if the Technical Group deter-
mines that such action would assist in
achieving the goals of the Agreement.
Any such wells may be turned on by the
Technical Group as long as a soil water
deficit has not been projected at the
monitoring site tied to the well.

o Well Turn-off Provisions

Soil-to-plant water balance projec-
tions for July 1 will be based on the

soil water and leaf area monitoring data collected during late June of that year. Transpiration projections for plants at the site shall be made according to the methods presented in Section III.D, with the transpiration curve evaluated for the second one-half of the growing season between DOY=186 and DOY=289 (DOY refers to the day of year as numbered consecutively 1 through 365). Soil water content shall be estimated according to methods presented in Sections III.F and III.G.

Soil-to-plant water balance projections will be made on October 1 by evaluating the site's transpiration curve through the following growing season as described in Section III.D. The plant-required water will be compared to the plant-available soil water computed by the techniques in Section III.G but adding estimated additional soil water that would be available to plants from precipitation in the following amounts:

- One-half of the annual average precipitation for the monitoring site shall be added to the computed plant-available soil water. Average annual precipitation has been computed as averages per quadrangle using an isohyetal map

(LADWP, 1976). The estimated
one-half of precipitation is the
amount of water estimated to be
available as a long-term,
Valley-wide average based on
results from vegetation mapping
and projection of ET (Groeneveld,
1988). The amount of precipita-
tion calculated in the soil water
projections will be reduced under
the following circumstances:

If the actual runoff average
for the previous runoff year and
the forecasted runoff for the
then-current runoff year is less
than 70% of average, 40% of the
average precipitation for the
monitoring site shall be added
to the computed plant available
soil water.

If the average of the actual
runoff for the two previous
runoff years and the forecasted
runoff for the then-current
runoff year is less than 75% of
average, 30% of the average
precipitation for the monitoring
site shall be added to the
computed plant-available soil
water.

- Pursuant to Section II.C of the
  Agreement, the Technical Group has

designated certain pumping wells
which are exempted from linkage to
vegetation sites and are not subject
to the well turn-off provisions.
These exempt wells are specialized
cases which are the sole source of
supply water for towns, irrigation,
and fish hatcheries, or their opera-
tion does not affect areas with
groundwater-dependent vegetation.
The wells exempted are 354, 341, 330,
332, 118, 351, 356, 357, 344, and
346. These exemptions will be recon-
sidered as appropriate.

o Well Turn-on Provisions

   - Wells that have been turned off
      under the above provisions may be
      turned on if soil water in the
      monitoring site area has recovered
      to the estimated water needs of
      the vegetation at the time the
      wells were turned off.

      The required soil water level
      recovery in a monitoring site may
      be revised if an evaluation of
      vegetation conditions and other
      relevant factors indicates such a
      need.

      If, subsequent to the time that
      the well was turned off, the
      amount of soil water that

triggered the turn-off of a well has been revised, the well may be turned on once soil water has recovered to the revised water needs level for the vegetation.

- If no significant vegetation decrease or change has occurred, and a well has been turned off because of a projected soil water deficit, such a well may be turned on by DWP to supply water to increase the available soil water in the area of the monitoring site.

- If a significant vegetation decrease and/or change has occurred, and a well has been turned off, the well may be turned on, if necessary, to supply water to avoid additional decreases or changes, and/or to supply water to mitigate such impacts. The following guidelines shall be used by the Technical Group to determine whether such wells should be operated:

     The groundwater extracted will be used only within the area of the well, and no extracted water will be exported from that area; and

The Technical Group has determined that the application of water is a necessary part of mitigation for the affected area; and

Supplying water to the area from a source other than the turned off well is infeasible; and

If it is determined that an alternative supply is necessary and can feasibly be made available to the affected area, it will be made available and the well will be turned off; and

The Technical Group has determined that the need and value of the mitigation is greater than the impacts, if any, that may result from the well operation, and that any such impacts will be avoided or acceptably mitigated; and

Regular operation of the well may be resumed once the mitigation plan for the affected area has been implemented and the Technical Group determines that operation of the well will not result in significant decreases or changes in the vegetation.

b. Surface Water Management - Types B and C

Should water balance calculations project that
less soil water will be available in an area of
Type B or C vegetation than is required by the
vegetation, and should it be determined that
the projected soil water deficit is not
attributable to groundwater pumping, it will
then be determined whether the projected
deficit is attributable to changes in surface
water management practices. If the projected
soil water deficit is attributable to changes
in surface water management practices, such
action as is feasible and necessary will be
taken to avoid significant decreases and
changes in the vegetation.

3. Type D Vegetation

Type D vegetation, comprised of riparian and
marshland cover, is currently monitored and managed
in accordance with procedures described below.
This vegetation type tends to be concentrated in
areas of streams, swales, water conveyance canals,
springs, and flowing wells. Since Type D vegeta-
tion is more sensitive to water deficits that
Types B or C vegetation, the effectiveness of
existing monitoring and management procedures will
be evaluated, and appropriate procedures and tech-
niques will be developed to assist in achieving the
vegetation management goals and principles of the
long-term Agreement.

The Technical Group evaluation will consider the
following factors: 1) the need for and the loca-
tion of additional monitoring sites;

2) site-specific monitoring requirements which may include measurement of water tables, soil moisture, flow rates from springs and flowing wells, water availability at areas of major seeps, vegetation conditions, and visual observations from on-site inspections; 3) the frequency of making on-site visits; 4) the linkage of wells to monitoring sites; 5) the appropriateness of using the "water balance" projections to manage this vegetation type; and 6) well turn-off and turn-on provisions.

During the period that new monitoring procedures are being evaluated, the following procedures and techniques will be employed:

a. Groundwater Management

In addition to the provisions for management of Type B and C vegetation, groundwater pumping will be managed as follows to avoid causing significant decreases or changes in Type D vegetation:

i. The vegetation management maps will be used as a basis for establishing new regional monitoring sites in areas of Type D vegetation where groundwater pumping could potentially affect such vegetation. Visual monitoring at these sites will be conducted as necessary. Generally, monitoring will be by a field visit each month during the growing season, starting with April and ending with October, and by a visit every other month during the other portions of the

year. If indications of water deficit stress are observed, a determination will be made whether the cause of the problem is attributable to changes in surface water management practices or to groundwater pumping. This determination will be made in accordance with procedures set forth in Section I.C.

ii. If it is determined that a potentially severe water stress condition that could cause a significant decrease or change in vegetation attributable to groundwater pumping exists, then the wells affecting the area will be turned off unless sufficient water is supplied to the affected area to eliminate the water stress condition.

iii. If no significant vegetation decrease or change has occurred, and a well has been turned off because of projected water stress condition, the well may be turned on by DWP to supply water to eliminate the projected water stress condition in the vegetation in the area of the monitoring site.

iv. If a significant decrease or change in Type D vegetation has occurred and a well has been turned off, the well may be turned on, if necessary, to supply water to avoid additional decreases or changes and/or to supply water to mitigate such impacts. The following

guidelines shall be used by the
Technical Group to determine whether
such wells should be operated:

o The groundwater extracted will be
  used only within the area of the well
  and no extracted water will be
  exported from that area; and

o The Technical Group has determined
  that the application of water is a
  necessary part of mitigation for the
  affected area; and

o Supplying water to the area from a
  source other than the well that has
  been turned off is infeasible; and

o If it is determined that an alterna-
  tive supply is necessary and can
  feasibly be made available to the
  affected area, it will be made
  available, and the well turned off;
  and

o The Technical Group has determined
  that the need and value of the mitiga-
  tion is greater than the impacts, if
  any, that may result from the well
  operation, and that any such impacts
  will be avoided or acceptably miti-
  gated; and

o Regular operation of the well may be
  resumed once the mitigation plan for

the affected area has been imple-
mented and the Technical Group deter-
mines that operation of the well will
not result in significant decreases
or changes in the vegetation.

b. Surface Water Management

If, through field observation and other moni-
toring, it is determined that changes in
surface water management practices could affect
or has affected an area of Type D vegetation,
the Technical Group shall take such action as
is feasible and necessary to prevent signifi-
cant decreases and changes in the vegetation.

4. Type E Vegetation

a. Water Management

If a significant decrease or change in vegeta-
tion conditions from those which existed during
the 1981/82 runoff year is projected to occur
because of a reduction in the supply of water
to the affected lands, and the reduction is not
a result of an agreement of the parties pursu-
ant to Section IV.A of the Agreement, if
feasible, the supply of water will be immedi-
ately increased to avoid such a decrease or
change.

The Agreement recognizes that successive dry
years could result in insufficient water supply
to meet all needs. Section IV.A of the
Agreement provides that during periods of water
shortages, a program to reduce the amount of

irrigation water supply for Los Angeles-owned
lands may be implemented if such a program is
approved by the County Board of Supervisors and
the Department. Factors that will be consid-
ered in determining if such a program is to be
implemented include: 1) water use, supply, and
conservation in Los Angeles; 2) flows in the
Los Angeles Aqueduct System; 3) surface water
runoff conditions; 4) level of groundwater
extractions; and 5) extent of well turn-offs
implemented for purposes of environmental
protection.

C. <u>Impact Determination and Mitigation</u>

Among the primary goals of the Agreement are to manage
groundwater pumping and surface water management
practices as follows: 1) to avoid causing significant
decreases in live vegetation cover; 2) to avoid
changing a significant amount of vegetation from one
classification to a lower (alphabetically) classifica-
tion; 3) to avoid causing other significant effects on
the environment; and 4) in a manner consistent with
State and Federal laws pertaining to rare and
endangered species. If any of these goals are not
achieved, feasible mitigation of the affected area will
be implemented. However, mitigation is not considered
a primary management tool, but rather a secondary tool
that will be employed should impacts occur that are
inconsistent with the goals of the Agreement.

This section outlines a procedure for determining
whether decreases and/or changes in vegetation or other
significant effects on the environment have occurred or
are occurring in a given management area. It describes

the process the Technical Group will follow to ascertain whether a change is significant, and thus, whether it requires mitigation. It also describes how the Technical Group will develop and implement a mitigation plan and monitoring and reporting program.

1. Determination of Significant Impacts

    A significant decrease or change or other significant effect on the environment will be mitigated if it is measurable, attributable to groundwater pumping or surface water management practices, and significant. The Agreement provides that the determination of significance of an impact, and thus, whether it must be mitigated, will be made on a case-by-case basis. The steps in the case-by-case analysis are described below.

    a. Determining Measurability

        In determining whether a change in vegetation cover or composition is measurable, the Technical Group will consider all relevant factors, including:

        i.   Comparison of current vegetation cover and composition in the affected area with similar data taken during other time periods, including the 1984-87 vegetation inventory data.

        ii. Comparison of vegetation cover and composition at the affected area with vegetation data from one or more control sites located in areas which have

similar vegetation, soil, and
precipitation conditions.

iii. Comparison of the ratio of recently
deceased vegetation to live vegetation
in the affected area with other areas
not affected by pumping and with similar
vegetation cover and composition, soil,
and precipitation conditions.

iv. Use of air photo and remote sensing
techniques to assist in making compari-
sons of conditions during different time
periods and in mapping the affected area.

v. Comparison of data from randomly
selected transects with similar data
taken during other time periods,
including the 1984-87 vegetation
inventory data. This method will be
employed in areas where monitoring site
data does not exist, or where data
covers an insufficient time period.
Such transects will be performed as
described in Box I.C.1.a.ii.

A determination of measurability will be made
if any of the relevant factors considered
indicate even a small documentable change in
vegetation cover or composition has occurred.

BOX I.C.1.a.ii

TRANSECTS FOR
MONITORING VEGETATION RESPONSE TO PUMPING

Vegetation transects are included within the
Green Book to serve two purposes: 1) to
estimate transpiration from a monitoring site,
and 2) for use in determining whether vegeta-
tion has decreased or changed significantly
from the previous cover.

(1)   Detailed measurements of leaf area
      index shall be made at each of the
      monitoring sites using the techniques
      described in Section III.C. These
      measurements will be used to estimate
      evapotranspiration from the vegeta-
      tion at the monitoring site for com-
      parison to available soil water and,
      ultimately, to project plant-soil
      water balance and the need for water
      table recovery.

(2)   Vegetation transects shall also be
      used in cases of suspected vegetation
      changes due to groundwater pumping.
      However, rather than using the inten-
      sive sampling technique of
      Section III.D for calculating evapo-
      transpiration, plant cover shall be
      measured by the line-point technique
      described below.

      During the 1984-87 inventory, each
      parcel was sampled with at least five
      line-point transects of 100 feet in
      length, with sampling points at
      one-foot intervals, providing a
      two-dimensional representation of
      vegetation within the parcel. At
      each one-foot marker, the first con-
      tact with the uppermost layer of live
      plant cover was recorded. Cover and
      species composition were calculated
      from all sampling points along the
      transect.

      The 1984-87 inventory shall be used
      as a "baseline" to determine whether
      vegetation cover and/or species com-
      position has changed. This inventory

is the only one of sufficient accu-
racy to permit comparison. Future
line-point transects should be per-
formed in a similar manner as the
initial inventory to determine
whether vegetation has change, but
the technique may be modified to
permit detailed statistical compari-
son by randomly selected transects.
Statistical analysis will be used to
determine the measurability (statis-
tical significance) of vegetation
changes from the 1984-87 inventory
maps.

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b. Determining Attributability

Once it has been determined that there has been
a measurable vegetation decrease or change, it
must be determined whether the impact is attrib-
utable to groundwater pumping or to changes in
surface water management practices.

A determination of whether the impact is
attributable to groundwater pumping or changes
in surface water management practices will be
based on evaluation and consideration of
relevant factors, which may include:

  i. Recent and historic water table changes
      and response to pumping as measured at
      the monitoring site(s) closest to the
      affected area.

  ii. Comparison of soil water, depth to
       water, and degree of vegetation decrease
       or change at the affected area and at
       the control site(s) determined to have

similar soil type and vegetation composition and cover.

iii. Comparison of water table depths in the affected area with water table depths in the general region with soils, vegetation cover, and vegetation composition comparable to the affected site. New shallow piezometers may be installed and monitored, if necessary, to obtain relevant water table data.

iv. Rainfall differences that may exist between the control site(s) and the affected area.

v. Evaluation of the extent to which other factors unrelated to the effects of groundwater pumping may have contributed to the vegetation change or decrease. Such factors include drought, wet/dry climatic cycles, flooding, fungal blight, range management practices, wildfire, and off-road vehicles.

vi. Change in soil water within the root zone caused by a pumping-induced change in the water table.

vii. Review of surface water operations to determine if changes from past practices contributed to vegetation changes.

viii. A decrease in flow from a spring or flowing well.

If a decrease in flow from a spring or
flowing well occurs, the Technical Group
shall determine whether the decrease
corresponds to changes in groundwater
pumping and runoff. If, on the basis of
qualitatively evaluating the data, it
appears that the decreased flow corre-
sponds with increased pumping and
decreased runoff, the Technical Group
shall conduct a quantitative analysis of
the data, using one or both of the
methods described below, or any other
method developed by the Technical Group:

o The Technical Group shall perform a
   regression analysis of the relevant
   groundwater level, spring flow,
   runoff/recharge, and pumping data
   associated with the site (an example
   of applying this technique is found
   in the Technical Group's analysis of
   the water flow decrease at Reinhackel
   Spring).

o The Technical Group shall use the
   groundwater model of the area in
   question as a supplement to the
   regression analysis, or as a substi-
   tute for the regression analysis if
   the data are inadequate to develop a
   regression model. The model would be
   applied by evaluating groundwater
   level and spring flow changes in the
   area under the relevant
   runoff/recharge conditions that

existed under pumping and nonpumping scenarios. For example, the runoff/recharge conditions that existed during the period that the suspected impact occurred would be quantified and entered into the model. The pumping that occurred at that time would also be entered. Results of this run would be compared to a run with the identical runoff/recharge conditions and no pumping. Evaluation of the results would include an analysis of the difference in water levels and/or spring flow in the area to determine if the change that is calculated by the model is sufficient to conclude a pumping-related impact, given the assumptions and limitations of the model.

c. Determining Degree of Significance

Following a determination that there has been a measurable decrease in vegetation cover, and that the decrease or change was attributable to either groundwater pumping or surface water management practices, the following analysis shall be conducted to determine whether the measurable decrease or change is significant. Each of the following factors shall be evaluated and a determination made as to whether or not the impact is significant:

i. The size, location, and use of the area that has been affected.

ii. The degree of the decrease, change, or effect within the affected area.

iii. The permanency of the decrease, change, or effect.

iv. Whether the decrease, change, or effect causes a violation of air quality standards.

v. The cumulative effect of the impact when judged in relation to all such areas of the Owens Valley.

vi. The value of existing enhancement and mitigation projects addressing the environmental consequences of similar impacts.

vii. The impact, if any, on rare or endangered species and on other vegetation of concern.

viii. Whether the decrease, change, or effect affects human health.

d. Determining Significance of Other Effects on the Environment

Any other impacts, including decreases in recreational opportunities and decreases in wildlife habitats, shall be examined by the Technical Group in a similar manner to the procedures set forth above or by other appropriate procedures to determine whether a significant effect on the environment has occurred that is attributable to groundwater pumping or changes in surface water management practices.

2. Development and Implementation of a Mitigation Plan

If it is established that there has been a signifi-
cant decrease in live vegetation cover, or a
significant amount of vegetation has changed from
one vegetation classification to a lower classifica-
tion, or any other significant effect on the
environment has occurred, then any such significant
impact will be mitigated as soon as a reasonable
and feasible mitigation plan is developed. The
Technical Group is responsible for developing a
mitigation plan for the affected area, and the
Department will commence implementation of the plan
within 12 months after the significant impact has
been established. A written mitigation plan will
be prepared by the Technical Group and submitted to
the Standing Committee during this 12-month period;
however, the Technical Group is not precluded from
implementing any necessary interim mitigation
measures during this period.

a. In developing a mitigation plan, the Technical
    Group shall first establish a goal for the plan
    in conformance with the goals and principles of
    the Agreement. Thus, if there has been a
    significant decrease in live perennial vegeta-
    tion cover or a change in a significant amount
    of vegetation from one classification to
    another, a primary goal of the plan would be to
    avoid causing further decreases or changes.

    Generally, if there has been a significant
    decrease in vegetation live cover, the
    preferred goal of the plan would be to restore
    the same type of perennial vegetation cover in

the affected area; and, if there has been a
significant change in vegetation type, the
preferred goal of the plan would be to restore
vegetation to a vegetation community that falls
within the type classification depicted on the
vegetation management map. If any other signif-
icant effect on the environment occurs, the
goal of the plan would be to reduce the impact
to a level that is no longer significant.

Generally, compensatory mitigation (compen-
sating for an impact to the environment by
improving or enhancing an area located away
from the affect area) would not be a preferred
goal of a mitigation plan.

b. In selecting the means of achieving the goals
of the mitigation plan, the Technical Group
will consider the feasible alternatives. When
it is determined that the expertise of a consul-
tant would be beneficial, such consulting
services may be retained.

  i. Alternative means of achieving the miti-
gation goal that will be considered
include:

    o If the impact is attributable to
groundwater pumping, cessation of
groundwater pumping from wells that
affect the impacted area would be the
first consideration for mitigation.
Also considered will be a change in
the future management of groundwater
pumping from the well to avoid a
repetition of the impact.

o Surface water application to repair,
   rehabilitate, and/or restore the
   impacts will be considered as an
   alternative. Any water supply needed
   for the proposed mitigation shall be
   evaluated as to its potential for
   inducing further adverse environ-
   mental impacts.

o Revegetation of the affected environ-
   ment shall be considered as an alter-
   native. Generally, the preferred
   goal of revegetation would be to
   restore vegetation cover to the
   ecological viability which existed
   prior to the impact. A primary
   consideration in revegetation would
   be to use native species which grow
   in Owens Valley. Revegetation
   efforts will incorporate procedures
   to control weeds and fugitive dust.
   Full restoration may require a long
   period of time.

c. As part of each mitigation plan, the Technical
    Group shall develop a reporting and monitoring
    program. At least once per year, the Technical
    Group shall report, in writing to the Standing
    Committee, on the effectiveness of the mitiga-
    tion plan in achieving its goal.

    Should a mitigation plan fail to substantially
    achieve its goals, the Technical Group shall
    implement alternative, feasible mitigation, if
    any exists, that will achieve the goals. If no

such alternative exists, a new mitigation goal
will be developed and implemented for the
affected area. The Technical Group shall
report the change in writing to the Standing
Committee, together with reasons for the
change, and a new mitigation monitoring and
reporting program will be adopted by the
Technical Group.

d. If, through seasonal water balance calculations
or through other means, the Technical Group
projects that significant decreases or changes
in vegetation could occur, the Technical Group
will take such action as it deems feasible and
necessary to avoid the projected impact. Such
action would be in addition to the provisions
for automatic well turn-off.

D. Other Vegetation

For management purposes, vegetation in Owens Valley has
been divided into five management classifications based
on the dominant vegetation species. However, each
vegetation classification is comprised of vegetation
species other than the dominant species.

1. Management

Certain vegetation of significant environmental
value are not shown on the management maps because
they are not the dominant species. This vegetation
will be identified by the Technical Group for moni-
toring purposes on overlays to the management
maps. Areas of this vegetation include riparian
vegetation dependent upon springs and flowing

wells, stands of tree willows and cottonwoods, and areas with rare or endangered species. The monitoring sites will be located in areas where there is a potential for impact to such vegetation by groundwater pumping or changes in surface water management practices (although certain areas of rare or endangered species will be monitored, these areas will not be publicly identified on the management maps in the interest of protecting such vegetation).

If, through field observation, monitoring, and other evaluations, it is determined that groundwater pumping or changes in surface water management practices has resulted in severe water deficit stress that could cause a significant decrease or change in this vegetation, the Technical Group will take such action as is feasible and necessary to prevent significant impacts and to reduce any impacts to a level that is not significant.

2. Monitoring

Monitoring at each identified site will consist of one or more field visits during the period when groundwater pumping and changes in surface water management practices could affect such vegetation in an attempt to obtain advance knowledge of potential water stress. Shallow piezometers will be installed and monitored where and when deemed necessary (for rare and endangered species, only a qualitative assessment will be made in order to minimize the disturbance from monitoring). If an impact is suspected, more intensive measurements, such as vegetation transect procedures, would be undertaken as determined appropriate by the Technical Group.

3. Mitigation

    The procedures set forth in Section I.C will be
    used to determine whether an impact to vegetation
    of concern is measurable, attributable to ground-
    water pumping or changes in surface water manage-
    ment, and is significant, and thus, if a mitigation
    plan should be developed and implemented.

II. VEGETATION INVENTORY AND DEVELOPMENT OF VEGETATION
    MANAGEMENT MAPS

    Section II of the Agreement provides that management maps
    that classify dominant vegetation on the Valley floor into
    five types are to be used in achieving the goals of the
    Agreement. Vegetation inventories that were conducted by
    the Department between 1984 and 1987 were used in compiling
    these maps. This section describes the vegetation mapping
    methods and the development of the management maps. The
    Technical Group is conducting a cooperative study of the
    vegetation map data base (see Section V). As a result of
    this study, the vegetation management maps and portions of
    this section will be revised in the future. A mapping
    technique that employed air photo analysis, field checking,
    and sampling transects was used to document the dominant
    vegetation cover.

    Generally, vegetation inventories are used to document
    conditions over large land areas, providing a baseline for
    comparison to future vegetation cover. By regularly per-
    forming such a comparison, Inyo County and Los Angeles will
    monitor the effectiveness of the proposed hydrologic
    management techniques and make appropriate adjustments to
    meet the goals of the Agreement.

    A.   Inventory of Dominant Vegetation

         The dominant vegetation of a total of 227,160 acres of
         Los Angeles-owned land in the Owens Valley was inven-
         toried and mapped by LADWP between 1984 and 1987. All
         of the mapped acreage is within the Inyo
         County/Department of Water and Power Cooperative
         Vegetation Study area. The study area included
         portions of Chalfant Valley, Fish Slough, and the

entire area from Bishop to Owens Lake. The mapping
scale was 1:24,000.

1. Timing of Mapping Activities

The vegetation maps were produced through a
combination of laboratory and field work that was
divided for the north and south portions of the
Valley. Table II.A.1 shows--by quad--the time
frame of field work.

TABLE II.A.1

VEGETATION MAPPING - OWENS VALLEY

QUADRANGLE	MONTH & YEAR
Independence Bee Springs	September 1984 - September 1985
Manzanar	October 1985 - November 1985
Union Wash	November 1985 - December 1985
Lone Pine	January 1986 - March 1986
Blackrock	March 1986 - June 1986
Aberdeen	June 1986
New York Butte	July 1986
Tinemaha	July 1986 - August 1986
Fish Springs	September 1986
Big Pine	September 1986 - January 1987
Ulymeyer Spring	January 1987
Laws	February 1987 - April 1987
Poleta Canyon	May 1987 - July 1987
Fish Slough	July 1987 - September 1987
Bishop	September 1987

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a. Mapping for the area from Independence to Owens
Lake was accomplished during the period from
September 1984 to March 1986.

b. The Blackrock area north to Fish Slough and Chalfant Valley was mapped between March 1986 and November 1987.

2. Methods for Vegetation Mapping

LADWP lands were defined into parcels based on historic and current land use and on contiguous assemblages of plants with relatively similar cover and composition. Historic land-use maps were consulted, air photographs were analyzed, and field sampling was performed. Vegetation parcels were ultimately classified into recognized plant communities based on a classification system used by the California Natural Diversity Data Base (Holland, 1986).

a. Historical references were consulted, including water and land-use maps, and 1944, 1968, 1973, and 1981 aerial photos of Owens Valley.

b. Color prints of aerial photographs, at a scale of 1:12,000, from July 1981 were used for the initial delineation of vegetation parcels and for the actual field sampling. Black-and-white air photo prints from 1944, at a scale of 1:24,000, and 1968, at a scale of 1:12,000, were also used to verify abandoned agriculture.

c. The color and scale of the 1981 aerials permitted preliminary delineation of parcels on acetate overlays. The minimum mappable area for recognizing a parcel was selected at 20 acres. Areas of similar color and appearance were assumed to have somewhat uniform plant

cover and species composition. The contrasts
between types ranged from strong to very subtle.

d. Field sampling required visiting each parcel.
    Adjustments of the parcel boundaries were made
    in the field, if necessary. Field sampling of
    the vegetation in each parcel was accomplished
    by vegetation transect. The line-point tran-
    sect was chosen as the technique because it is
    a simple and rapid method to characterize
    vegetation cover (Kuchler, 1967).

    i.   The line-point method was adopted from
         techniques presented by Heady, Gibbens,
         and Powell (1959). A 100-foot metal
         engineer's chain (or tape), with 1-foot
         markers, was stretched over the
         vegetation selected for sampling.

    ii. At each 1-foot marker, the tallest plant
         cover as seen from a vertical projection
         was recorded; plants existing as an
         understory and nonleafy categories, such
         as ground cover and mulch, were not
         recorded.

    iii. A minimum of five transects were run on
         each parcel. If the vegetation cover
         was particularly heterogeneous, a quali-
         tative method was employed in selecting
         additional transects. The transect data
         were checked visually and additional
         transects were then run depending upon
         the degree of variability. If the
         transect data were highly variable, up

to seven additional transects were run.
Aerial photos were an aid in locating
the transects.

iv.   Transects were located visually by
      choosing lines that appeared to cover
      the representative units of vegetation
      within the parcel. With regard to the
      parcel area, transect locations were
      generally toward the center of the
      parcels in order to avoid transitional
      areas at the parcel edges.

e. The transect data collected in the field was
    evaluated to determine the percent cover of
    each species calculated by the total of the
    first contacts for the species divided by the
    total sampling points used. From these data, a
    final vegetation description was compiled for
    each parcel (Transect Sheet, Appendix A). The
    description includes the percent of live vege-
    tation cover and the percent composition of
    each plant species. Vegetation cover is
    defined as the crown cover of all live plants
    in relation to the ground surface. Species
    composition is synonymous with "relative cover"
    and expresses the percent contribution by a
    species to the land surface area covered by
    living plants.

f. The parcel boundary lines were transferred to
    orthophoto quadrangles at 1:24,000 scale. The
    final maps overlay the USGS 7.5-minute quads.
    Each parcel was numbered and has a
    corresponding vegetation description. The
    acreage of

each parcel was determined by planimetry, and the vegetation cover for the parcel was entered into a computer data base.

g. The final stage in mapping was the selection of a classification system. The system used is based on Cheatham and Haller's classification of California habitat types (Cheatham and Haller, 1975), as revised to plant community descriptions (Holland, 1986). This system was further refined for the Owens Valley using the data collected for this inventory. To suit the needs of the Cooperative Vegetation Study, six additional plant communities and a non-native vegetation and miscellaneous lands category were added.

The classification system used is primarily floristic; hence, parcels with similar species composition were grouped together. In instances where a parcel could fit into two different communities, factors such as soil type, water table depth, and landscape position were evaluated and used in determining the correct community.

B. <u>Projecting Evapotranspiration from Dominant Vegetation</u>

The transpiration from each of the mapped parcels was calculated based on data gathered during the Cooperative Vegetation Study and on data presented in the literature. Evaporation was estimated either (1) as one-half the average precipitation for the quadrangle in which the parcel was located, or (2) as an amount of water equal to one-half the average

precipitation estimated as in (1) added to a fixed, one-dimensional rate (Table II.B.4) which is multiplied by the area of bare ground. The quadrangle-average precipitation was computed from maps of isohyetal contours (LADWP, 1976).

1. The transpiration values for the six most dominant Owens Valley plant species were obtained from the Cooperative Vegetation Study, Phase I (Groeneveld et al, 1986). The report yielded equations for transpiration and leaf area index for each species as a function of the day of the year based on field data. The equations were calculated to represent the annual amount of water transpired on a site with 100% cover by the species. Therefore, to obtain parcel transpiration by species, the values were expressed as a rate per 100% cover that could be decremented by the actual fractional cover measured within the parcel. The transpiration equations for six dominant perennial species are presented in Table II.B.1.

2. Annual values for transpiration based on percent cover for eight other species were determined from the literature (Table II.B.1).

3. For the species for which transpiration was neither documented by the Cooperative Studies nor was available in the literature, transpiration was set equivalent to the weighted mean for the documented species that occurred within the parcel. If transpiration rates of no species were known within a parcel, the annual transpiration rate for all other parcels within the quadrangle was assigned.

TABLE II.B.1

TRANSPIRATION VALUES

SPECIES SYMBOL	COMMON NAME	TRANS. (in.)	SOURCE
ATCO	Shadscale	8.00	Groeneveld*
ATTO	Nevada Saltbush	17.30	Groeneveld
CHNA2	Rubber Rabbitbrush	36.93	Groeneveld
DISPS2	Saltgrass (sandy soil)	10.40	Groeneveld
DISPS2	Saltgrass (silty soil)	20.33	Groeneveld
SAVE4	Greasewood	35.89	Groeneveld
SPAI	Alkali Sacaton (sandy soil)	11.11	Groeneveld
SPAI	Alkali Sacaton (silty soil)	19.41	Groeneveld
ARTRT	Basin Big Sagebrush	4.06	Branson, et al Miller, et al
CELA	Winterfat	2.99	Branson, et al Moore, et al
GRSP	Spiny Hopsage	5.20	Branson, et al
TEAX	Longspine Horsebrush	3.31	Branson, et al
SAGOV	Goodding Willow	48.00	Robinson
SALIX	Willow	48.00	Robinson
TARA	Saltcedar	66.00	Gay
IRAG	Irrigated Agriculture	35.04	DWP Records
URBAN	Owens Valley Towns	24.00	DWP Records

* Cooperative Vegetation Study - Phase 1

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4. Evaporative water loss from precipitation was estimated to be 50 percent of the average annual precipitation in the quadrangle applied over the entire acreage (Groeneveld, 1989). Additional evaporation values have been added for those areas influenced by surface water (Table II.B.4.). These one-dimensional bare soil evaporation rates were estimated and were used to calculate an average bare-soil evaporation rate.

TABLE II.B.4

EVAPORATION VALUES

CLASSIFICATION	COMMON NAME	EVAP. (in.)	SOURCE
Various	Parcels Irrigated with Stock-water or Operational (Surplus) Water Releases	7.20	Estimated*
60000	Riparian	24.00	Estimated*
40000	Native Grass Meadows	7.20	Estimated*
13100	Permanent Bodies of Water	60.00	DWP Reservoir Records*
13200	Intermittent Bodies of Water	36.00	Estimated from DWP Reservoir Records*

* Technical Group, September 25, 1986; Inyo County/LADWP/USGS Cooperative Owens Valley Groundwater/Vegetation Studies, January 22, 1987

NOTE: These evaporation values are applied to the bare ground in the parcel (or to the water surface in the case of lakes and ponds) in addition to one-half the average annual precipitation in the quadrangle applied as evaporation over the entire acreage.

5. For each parcel, as represented on the sample print-out in the Appendix A, the following information can be found: annual transpiration in feet, annual transpiration in acre-feet, annual evaporation in feet, annual evaporation in acre-feet, annual evapotranspiration (ET) in acre-feet, annual ET in feet, and annual ET in inches.

C. Vegetation Management Maps and Goals

The previous discussion focused on the development of
vegetation community maps and the calculation of
average annual evapotranspiration from each parcel.

The plant community classification and plant water use
calculations for parcels were combined to produce a
series of management maps.

The management maps, which are attached to the
Agreement, classify 227,160 acres of vegetation into
five management types--A through E. The five
color-coded categories were derived based on the
vegetation community maps previously described and on
water use. The categories, in increasing alphabetical
order, generally show increasing water use.

The maps depict each color-coded category as either
inside or outside an area of potential impact that is
based on a worse-case pumping and drought condition.
The derivation of the potential impact area is more
fully discussed in Section IV. Other features on the
maps include roads and towns, vegetation monitoring
sites, and LADWP pumping wells.

Vegetation was assigned to Types A through E by first
calculating the average ET of each community. The
results are presented in Table II.C.

TABLE II.C

CODE#	COMMUNITY	AVERAGE ET (INCHES)
14000	Barren Lands	3.12
34100	Mojave Creosote Bush Scrub	3.60
34210	Mojave Mixed Woody Scrub	3.48
34300	Blackbrush Scrub	4.08
35100	Great Basin Mixed Scrub	4.20
35210	Big Sagebrush Scrub	4.44
36110	Desert Saltbush Scrub	4.08
36120	Desert Sink Scrub	5.76
36130	Desert Greasewood Scrub	4.68
36140	Shadscale Scrub	3.60
46000	Alkali Playa	2.04
35400	Rabbitbrush Scrub	7.08
36150	Nevada Saltbush Scrub	7.68
45310	Alkali Meadow	11.04
45320	Alkali Seep	13.80
45340	Rabbitbrush Meadow	10.68
45350	Nevada Saltbush Meadow	9.60
52320	Transmontane Alkali Marsh	26.04
61610	Great Basin Riparian Forest	40.44
61700	Mojave Riparian Forest	33.12
63600	Great Basin Riparian Scrub	36.84
63810	Tamarisk Scrub	17.28
11000	Irrigate Agriculture	38.04
13100	Permanent Lakes/Reservoirs	62.88
13200	Intermittent Ponds	39.12
45330	Rush/Sedge Meadow	17.04
45500	Non-native Meadow	27.48
76100	Black Locust Woodland	25.68

1. All vegetation communities which had estimated annual evapotranspiration approximately equal to or less than the average annual precipitation (5.72 inches for all quads) were classified as Type A management areas and are shown as white on the management maps. Type A consists of all parcels in communities with average ET less than or equal to 5.76 inches.

The remaining vegetation communities for the entire mapped area were sorted using the computer data base to determine other parcels, regardless of the vegetation community, which had an estimated annual evapotranspiration rate less than the quadrangle-average precipitation. These parcels were also included in Type A classification.

2. Scrub communities with an estimated average annual evapotranspiration greater than estimated average precipitation within the quadrangle were classified as Type B. Type B vegetation primarily includes the Rabbitbrush Scrub and Nevada Saltbush Scrub communities and is shown as yellow on the management maps.

3. All grass-dominated vegetation parcels with an estimated annual evapotranspiration greater than quadrangle-average precipitation were classified as Type C and represented in green on the management maps.

4. All parcels dominated by riparian and marshland vegetation with an estimated annual average evapotranspiration greater than precipitation were classified as Type D and represented as red on the management maps.

5. All lands provided with surface water for irrigation, including enhancement/mitigation projects, recreation areas, wildlife habitats, stock water supplies, and water spreading areas, are classified as Type E and are shown as blue on the management maps.

III. VEGETATION MONITORING

Monitoring is the means to determine whether management of
groundwater and surface water will achieve the goals of the
Agreement. The intensity of the monitoring effort within
the Owens Valley is structured for vegetation type and loca-
tion, whether outside, on the periphery, or within a well
field. Monitoring intensity will be greatest within well
fields and will lessen with distance away from the pumping
wells.

Within well fields, vegetation will be monitored using
sites established to permit projection of plant water
balance according to Sections III.D through III.G.

The correlation of individual wells and existing monitoring
sites is summarized in Table I.C.2.

Future monitoring sites may be added based on the criteria
set forth in Section I.C.

A.   Locating and Overlaying Monitoring Data

The monitoring program will require a data base which
can tie geographic information to historic and current
hydrologic conditions and vegetation data. As new
concepts are developed and agreed upon, such as remote
sensing and geographic information systems (see
Section V. "Further Studies"), they will be integrated
into the monitoring system.

1.   Incorporation of Existing Data

Existing data will form the data base to interpret
vegetation vigor and community changes.

a. Maps of Vegetation and Soils

    Both the soil inventory of Owens Valley, con-
    ducted by the Soil Conservation Service in the
    mid 1980s, and vegetation data from the 1984-87
    Cooperative Studies Vegetation inventory will
    be utilized.

b. Areas of impacts from changed water management
    practices and resultant mitigation, if any.

c. All hydrologic features, such as lakes, canals,
    and streams (updated as necessary).

d. Location and data from pumping wells, test
    wells, and monitoring sites.

e. Interpretive features from the hydrologic and
    vegetation maps. A mixture of permanent and
    updatable information would be placed on one or
    more overlays, including:

    i.   Vegetation management classes (A through
         E as written in the Agreement).

    ii. Areas of rare or endangered species
         (although certain areas of rare and
         endangered species will be monitored,
         these areas will not be publicly
         identified on the management maps in the
         interest of protecting such vegetation).

f. Land ownership maps.

g. USGS quadrangle maps.

h. Cultural features, such as roads, towns, camp-
    grounds, and bicycle or equestrian paths.

i. Land use maps showing irrigation.

j. Burned areas resulting from accidental fires or
    through range management.

B. Remote Sensing

Remote sensing is a valuable tool for land management.
At present, the remote sensing program is presented as
a study in Section V. The remote sensing program will
be presented here once it has been tailored to the
Owens Valley.

C. Monitoring Leaf Area and Plant Recruitment

At sites where water balance projections are made, leaf
area index (LAI) will be used to compare vegetation
growth among sites and growing years and to project
seasonal plant water use. LAI will be evaluated by the
point frame during expected peak leaf growth. Under
nondrought conditions and without excessive summer
rains, the growing season peak has been found to occur
at approximately the mid-point of the calendar year
(Groeneveld et al, 1986).

Quantitative yearly recruitment inventories at all
monitoring sites will include woody and herbaceous
perennial species, and weedy and nonweedy annual
species. The intent of the recruitment studies is to
determine community processes in relation to hydrologic
management and ambient conditions, and to determine
long-term trends of vegetation dynamics (see Section V).

1. Leaf Area Evaluated by Permanent Transect

   a. Transects are to be 100 m long, marked by
      permanent stakes. The beginning of each tran-
      sect, which is the zero point for point-frame
      records, will be marked. Facing along the
      transect from the zero point, right- and
      left-hand sides will be noted. The transect
      will receive point-frame measurement from the
      right-hand side only.

   b. Sub-transects of 30 m length will be located on
      each 100-m transect; these will also be marked
      by permanent stakes.

   c. Workers will avoid walking across the transect
      line in order to preserve the vegetation cover.

2. Leaf Area to be Determined by Point Frame

   Point-frame data will be collected to estimate ET
   for the monitoring sites and to measure vegetation
   composition and LAI.

   a. Point-frame pin intervals will be 30 cm. Pin
      length will be sufficiently long to permit
      measurement on plants of the stature
      encountered at each transect.

   b. A measuring tape will be stretched between the
      permanent stakes at each end of the transect.
      The stretched tape aligns the point frame, and
      guides pin interval location.

   c. Pins will be sharpened to a point on the end
      used for measurement.

d. All contacts with plant parts by the sharpened
pin points lowered from the frame will be
recorded.

   i. The first contact of the pin with the
      transpirative surface (leaf tissue
      and/or stem tissue, depending upon
      species) will be recorded by species.

   ii. Subsequent contacts of the pin with
       transpirative surfaces will be recorded
       by species.

   iii. Contact of the pin point with dead plant
        material lying on the ground will be
        recorded as "mulch."

   iv. Contact with standing but nontranspiring
       plant material will be recorded as
       "standing mulch." Only one "standing
       mulch" per pin is recorded.

   v. Contacts consist of either transpirative
      foliage, mulch, standing mulch, or bare
      ground.

e. Total number of hits on the more abundant Owens
   Valley species can be used to calculate leaf
   area index. There are six species which
   dominate the Valley floor. Transpiration data
   has been collected for each of the six species
   to enable projection of soil-to-plant water
   balance at monitoring sites (Groeneveld et al,
   1986). Table II.C.2.e presents the species
   with recognized standardized abbreviations
   (USDA SCS, 1971).

TABLE III.C.2.e

ABUNDANT SPECIES OF THE OWENS VALLEY FLOOR

SPECIES	RECOGNIZED ABBREVIATION
Atriplex torreyi	ATTO
Chrysothamnus nauseosus	CHNA
Sarcobatus vermiculatus	SAVE
Sporobolus airoides	SPAI
Distichlis spicata	DISP
Atriplex confertifolia	ATCO

3. Applying Leaf Area Data by Normal Curve

The leaf area measurements are used for calculating
plant water requirements. At present, this
technique which uses plant cover is under review to
determine whether leaf area index permits more
accurate estimation of transpiration (see
Section V, dealing with further studies).

A normal curve will be used to describe leaf area
through a growing season using time as the
independent variable. The ends of this curve have
been fitted in order to approach zero leaf area on
March 25 and October 15 (DOY 84 and 289, respec-
tively).

a. The peak of the growing season will be estab-
    lished as July 4 (DOY 186). The magnitude of
    this curve at its peak will be determined by
    the late June point-frame measurements obtained
    at each of the monitoring sites.

b. Leaf area during any day of the summer will
then be simulated according to a fitted normal
curve:

$$LAI_j = \sum_{i=1}^{n} LAI_{max_i} \, e^{\frac{-(t-186)^2}{3000}}$$

where: t = day of year (DOY)
           i = ith species
           j = jth site
           LAI_{max} = peak season LAI

4. Leaf Area Monitoring will Occur Three Times Each
Year

a. Each 100 m permanent transect will be monitored
within one week before and two weeks after
summer solstice. The 30 m sub-transect data
for this time period will be extracted from the
100 m data.

b. Within one week before and two weeks after
April 21, and again for August 21, point-frame
measurements will be taken at the 30 m
sub-transect.

5. Plant Recruitment Studies (see also Section V)

Permanent belt transects will be used to evaluate
the recruitment of herbaceous and woody perennial
species.

a. Ten belt transects, 1 m wide and each 10 m long, will be located on the left-hand side of the transect as viewed facing along the transect from the zero end.

b. Evaluation of belt transects will be performed during three periods:

    i.   Herbaceous species will be evaluated within one week of the April point-frame measurements.

    ii. Herbaceous species will again be evaluated within one week of the peak season (late June) point-frame measurements.

    iii. Both herbaceous and woody perennial species will be evaluated within one week of the August point-frame measurements.

c. Data collection for nonwoody species within the belt transects will be standardized to enable easy data analysis.

    i.   All species will be identified by their standardized abbreviations.

    ii. All individuals of herbaceous perennials and annual species will be recorded.

d. Data collection for woody perennials that are recognizably younger than surrounding vegetation will be recorded into three age classes:

i.   Plants germinated during the current year

    ii. Plants germinated the previous year

    iii. Plants germinated two or more years
         previously but still having recognizable
         juvenile characteristics, such as:

         o   Comparatively small stature

         o   Relatively thin stem-base cross
             section

         o   Lack of flowering/seed set

D. Projecting Transpiration through the Growing Season

    Transpiration requirements of projecting soil-to-plant
    water balance for the permanent monitoring sites will
    be based on the leaf area measured for each species at
    the peak of the growing season. Peak season LAI has
    been chosen for estimation of transpiration since this
    is the time when the rate of change in leaf area is
    minimal. Normal curves of leaf area will be calculated
    using actual monitoring data as described under
    Section III.C.3.

    The method for calculation of transpiration is under
    investigation in Section V with the study of methods
    for estimating leaf area. The most accurate and
    efficient method for estimating transpiration at
    monitoring sites will be determined through this study
    and changes to the following technique may occur.

The calculation of transpiration for each species at a monitoring site through the growing season will necessitate summation of each day's projected leaf area multiplied by each day's unit leaf-area transpiration. Transpiration will be apportioned using quadratic curves established or adopted for each species from data obtained under nondrought conditions. It is realized that the Valley-floor plant species have the capability to reduce transpiration during periods of soil water deficit and, therefore, actual unit-leaf-area transpiration rates will often be less than those projected using data from nondrought conditions. Use of transpiration data gathered under relatively normal soil water conditions provide a safeguard against possible underestimation errors during field measurement.

The transpiration requirement determined using the linked curves will be compared to the available soil water to project whether sufficient water remains to supply the vegetation for the upcoming growing season.

1. Polynomial curves have been developed to describe unit-leaf-area transpiration using data established for each of the abundant species that grow on the Owens Valley floor.

    a. Transpiration is represented by second order polynomial equations which describe downward-opening parabolas. Day of year (DOY) was used as the independent variable. "X" intercepts for this curve were chosen to be the approximate dates of leaf out and leaf drop: March 25 and October 15 (DOY 84 and 289, respectively).

$$Q_j = \sum_{i=1}^{n} \beta_{0i} + \beta_{1i}t + \beta_{2i}t^2$$

where: t = day of year
j = jth site
i = ith species
β = regression derived constants

b. The polynomial curves for each species have
been calculated using data excerpted from the
Cooperative Studies data base. The data chosen
represent relatively normal conditions for the
plants with the water table in its historic
positions. Seasonal curves of transpiration
for each species and each site are used to pre-
dict peak mid-season transpiration values (on
DOY 186). These peak values are then averaged
for each species. Polynomial regression is
then performed using the mean peak-season
transpiration and the zero points for the start
and finish of the growing season on March 25
and October 15 (DOY 84 and 289, respectively).

c. The Cooperative Studies data base has permitted
the establishment of curves for the six abun-
dant Valley-floor species. The predictors for
these curves will be used to calculate tran-
spiration on a unit-leaf-area basis. The
curves represented in Table III.D.1.c predict
transpiration as either volume (1 m^{-2}d^{-1})
or as a one-dimensional value (mm d^1).

TABLE III.D.1.c

POLYNOMIAL PREDICTORS FOR
TRANSPIRATION OF DOCUMENTED SPECIES*

SAVE4:   Q   = $-4.78 + 0.0823t - 0.000205t^2$

CHNA2:   Q   = $-4.140 + 0.0898t - 0.000250t^2$

ATCO: Q   = $-0.611 + 0.0190t - 0.00051t^2$

ATTO: Q   = $-2.290 + 0.0462t - 0.000125t^2$

DISP2:   Q   = $-2.470 + 0.0496t - 0.000132t^2$
(sandy soil)

DISP2:   Q   = $-5.330 + 0.1060t - 0.000291t^2$
(silty soil)

SPAI: Q   = $-2.840 + 0.0516t - 0.000137t^2$
(sandy soil)

SPAI: Q   = $-5.50 + 0.1010t - 0.000279t^2$
(silty soil)

* t = DOY

d. The remainder of the Valley-floor species did
    not receive individual transpiration measure-
    ments. For the species for which transpiration
    was neither documented by the above studies nor
    was available in the literature, transpiration
    was set to the weighted mean for the documented
    species that occurred within the transect at
    each monitoring site.

2. Calculation of Transpiration at Each Monitoring Site

    For each plant species at each site, transpiration
    through any time period during the growing season
    will be calculated for each day by multiplying the
    leaf area (determined using a normal curve des-
    cribed in Section III.C.3) by the transpiration
    presented in Section III.D.1.

a. The per-species water use will be calculated
    for the desired time period by summing the
    daily product of leaf area and transpiration
    through the days of the desired period.

b. The total transpiration for the vegetation at
    each monitoring site will be calculated as the
    sum of transpiration for each species or
    species grouping evaluated through the desired
    time period.

    i. If an estimation of transpiration for a
        monitoring site is desired for the
        entire growing season, the computation
        will be evaluated through the period
        between leaf out (DOY is 84) and leaf
        drop (DOY is 289).

    ii. Transpiration for a monitoring site
        through a portion of the growing season
        will be calculated in the same manner,
        but the calculation will be between the
        selected starting and ending days. For
        example, if the second half of the grow-
        ing season is chosen, the calculation
        will be performed between days corre-
        sponding to mid-season (DOY is 186) and
        leaf drop (DOY is 289).

c. The formula for this computation is:

$$Q_j = \sum_{i=1}^{n} \int_{t\,start}^{t\,end} \left[\left(LAI_{max_i} \, e^{\frac{-(t-186)^2}{3000}} \right) \left(\beta_{0i} + \beta_{1i}t + \beta_{2i}t^2 \right) \right] \, dt$$

where:
t = day of year (DOY)
j = jth site
i = ith species
β = regression derived constants
LAI_{max} = leaf area index measured during the growing season peak

E. Annual Biomass Measurements

1. Introduction

   Annual herbage productivity measurements are currently being collected on Owens Valley plant communities in conjunction with the Benton-Owens Valley Soil Survey. Long-term monitoring sites have been selected on several of the plant communities and soil types. Data is collected in April, May, and June during peak growth.

   Productivity accurately reflects the vigor or health of a plant or community. Changes or modifications of any growth factor, such as soil fertility, soil moisture, rainfall, or the biotic influences of insects, rodents, or livestock grazing, affect the vigor and, therefore, the productivity of a plant (Cook and Stubbendieck, 1986).

2. Method

   A double-sampling method (Wilm, et al, 1944; Hilmon, 1959) is used in deriving production and composition determinations. A study area is selected for each soil taxonomic unit, and is based

on uniformity of vegetation within that unit. Ten
random plots are selected. Plot size varies depend-
ing upon the vegetation density. The following
plot sizes and shapes are used for sampling:

   .96 ft² circular   - meadow communities
  9.6 ft² rectangular - shrub and shrub/grass
                                communities
  96. ft² rectangular - sparse shrub communities

Nested plots (9.6 ft²/96 ft²) are also used in
sparse shrub stands in years with heavy annual forb
production.

A weight unit is established for each species in
the study area, and the new growth is clipped and
weighed. A weight unit may be a branch of a shrub,
half of a grass plant, or ten forbs of average
size. Weights are then estimated, based on the
weight unit, for the species in each of the ten
plots. Two plots are then selected for harvest-
ing. They must include all or most of the species
in the estimated plots. Green weights are taken
for all the species in both plots. The clipped
growth is air-dried for three weeks and reweighed.
Regression analysis is applied to the data with
estimated weights as the dependent variable and
clipped weights as the independent variable. All
estimated values are then adjusted by the
regression equation. Production, in pounds per
acre, can then be calculated:

$$\frac{\text{Weight of all plots}}{\text{\# of plots}} \times \% \text{ dry weight} \times \text{plot correction factor} \times \text{plot size conversion factor}$$

3. Application of Production Data

    Ten production sites have been selected as
    long-term well field monitoring sites
    (Table III.E.3). Nine sites are located outside
    vegetation management zones, as determined by the
    Cooperative Agreement. The Division soil site is
    located east of Blackrock Springs, within a
    predicted drawdown area although no drawdown has
    occurred, and the site is being redesignated as a
    control site.

    The data will be used to provide a qualitative
    evaluation of the influence of precipitation on
    vegetation productivity. It will be compared with
    leaf area and vegetative cover data collected at
    control sites to evaluate the change in vegetation
    over time. The data collected at the control sites
    and at the productivity sites will be compared to
    monitoring sites with similar soils and vegeta-
    tion. This comparison will be utilized to quali-
    tatively evaluate the effects of fluctuations in
    precipitation and the resulting changes in vege-
    tation vigor.

F. Soil Water Measurements

    Permanent monitoring sites have been established.
    These sites are located (1) within well fields where
    water tables are known or expected to fluctuate due to
    groundwater pumping, and (2) in control areas outside
    of the influence of well field pumping to provide for
    comparison to plant responses within the well fields.

TABLE III.E.3

LONG-TERM PRODUCTION MONITORING SITES

Annual productivity measurements are being collected on Owens Valley plant communities in conjunction with the Benton-Owens Valley Soil Survey. Data is collected during the months of April, May and June when vegetation has reached peak growth. Current year production (1989) compared to previous years' production are shown below.

WELL FIELD AREA	SOIL NAME & TEXTURE *	TRANSECT REFERENCE	PHOTO NO.	QUAD	VEGETATION PARCEL NO.	CLASSIFICATION CODE	PRODUCTION #/AC (% LIVE COVER) 1985	1986	1987	1988	1989
Bairs-George Control	Lubkin GR-LS	85-114	12-6	Manzanar	1	34210		596 (19)	57 (13)	77 (16)	120 (11)
Symmes-Shepherd Control	Manzanar SL	84-22	10-19	Independence	148	45310	3005 (47)	2139 (34)	843 (24)	1103 (25)	1108 (21)
Symmes-Shepherd Control	Mazourka S	84-25	8-27	Bee Springs	2	36130	385 (10)	804 (16)	82 (7)	128 (9)	82 (6)
Taboose-Aberdeen Control	Division[1] VFSL	85-112	13-17	Blackrock	69	36120		723 (14)	179 (9)	222 (8)	177 (9)
Independence-Oak Control	Shondow L	85-70	12-19	Independence	79	45310	1204 (36)	1141 (40)	704 (29)	693 (25)	599 (29)
Independence-Oak Control	Winnedumah SIL	83-30	11-18	Independence	95	36150		1287 (25)	571 (27)	799 (27)	501 (17)
Big Pine-Crater Mtn. Control	Hessica SL	87-ET-110	14-36	Uhlmeyer	54	36120			252 (11)	194 (10)	244 (10)
Bishop-Warm Springs Control	Westguard S	87-ET-143	20-11	Big Pine	21	36120				105 (7)	137 (10)
Bishop-Warm Springs Control	Lucerne GR-LS	87-ET-197	25-4	Bishop	172	35100				280 (25)	36 (9)
Bishop-Warm Springs Control	Poleta S	88-ET-9	23-21	Laws	185	36140				173 (11)	40 (10)

* Soil Texture:

    GR-LS = gravelly loamy sand
        S = sand
      SIL = silt loam
    VFSL = very fine sandy loam
        L = loam

[1] Name change--was Numu

When groundwater pumping lowers a shallow water table below the effective root zone of the plants, retained soil water provides a supply for the vegetation for an uncertain period. The period that the retained soil water can maintain the vegetation is determined by type and cover of the vegetation, the water-holding capacity of soil, and starting water content. The objective for the measurements described in this section is to project a soil-to-plant water balance. This calculation determines whether the plant water requirement (project transpiration) will be met by the plant-available soil water.

Psychrometers are used for measuring soil water potential. Soil water potential is used to estimate the plant-available soil water. The limitation for plant withdrawal of soil water is governed by the logarithmic relationship of water potential to soil water content. Because of this relationship, assessment of the soil water available to plants would tend to have measurement errors compounded logarithmically if the measurements and interpretations relied solely upon soil water content. The monitoring techniques that have been chosen use direct measurements of soil water potential which are then converted to soil water content using the Miller method. This technique relates the soil water potential with soil water content using a technique suggested by Reuben F. Miller (Miller, 1983) and described and tested in Sorenson and others (1989).

Water potential measurements are being taken at one representative location within the soil of each monitoring site. Soil water measurements are obtained as close to the vegetation measured by the permanent transects as possible. Calculations of plant-available

soil water that are made from these measurements are then related to the water needs projected for the surrounding vegetation cover using the data established by vegetation transect.

The soil column at each of the monitoring sites is broken into four, 1 m-deep slices. The available water is calculated for each depth slice. The total water available to the plants is then estimated based on a summation of the plant-available water content for each slice located in the rooting zone.

1. Measuring Techniques for Evaluation of Soil Water

   Three types of measurements are used for in situ evaluation of soil water at monitoring sites. These measurements are obtained using soil psychrometers, piezometers, and neutron probes.

   a. Soil psychrometers are used to provide the necessary data for calculation of soil water potential and, through use of the "Miller Method," calculation of the soil water content by weight. For ease of implantation and removal, psychrometers are mounted within cassettes (details of cassette construction are shown on Figure III.F.1.a).

      i. Soil psychrometers are mounted into cassettes made of polyvinyl chloride (PVC) tubing. Three psychrometers are mounted at the tip of each cassette to provide for statistical evaluation of operation.

ii. Cassettes are constructed so as to be
     water tight in the event of water table
     recovery. Cassette heads are checked
     for water tightness following their
     construction.

iii. Psychrometers are installed at 0.5 m,
      1.5 m, 2.5 m, and 3.5 m depths. These
      depths have been chosen to be representa-
      tive of 1 m-thick soil slices extending
      to 4 m.

iv. Psychrometers will not be implanted into
     the water table.

v. Installation of psychrometers follows
    the procedure outlined in
    Box III.F.1.a.v. The psychrometer leads
    are accessed through insulated boxes
    buried 10 cm below the soil surface (see
    Figure III.F.1.a). Fiberglass
    insulation is packed over the tops of
    the psychrometers within the box to
    further reduce the effect of
    near-surface temperature gradients.

BOX III.F.1.a.v

INSTALLING PSYCHROMETERS
FOR THE MONITORING PROGRAM

STEP 1: Assemble the following items:
          Clay-water slurry of the consis-
          tency of honey
          Soil cans with zip-closure bag
            liners (6-1/2" x 5-7/8")
          2 Stainless steel mixing bowls of
            6-quart capacity

Large zip-closure bags
  (10-1/2" x 11-3/4")
2-inch Soil auger with
extensions, wrenches, and a
rubber mallet
Measuring tape with metric markings
Madera sampler and soil cans for
  volumetric soil sampling
Indelible felt-tip marker
Cooler and electrical tape

STEP 2: Select implantation site. This
should not be on a low spot and
should be within 30 m of the
permanent transect described in
Section II.A.1.

STEP 3: Measure and mark the depth desired
for the psychrometer on the shaft of
the auger. Also, place marks at 5 cm
below, and 15 cm and 45 cm above the
desired implantation depth.

STEP 4: Core, and reserve to the side of the
hole, all of the soil excavated down
to a point 45 cm above the intended
depth for the psychrometer.

STEP 5: Core and reserve the next 30 cm of
soil. Seal within a large plastic
zip-closure bag and place in bowl A.

STEP 6: Core the next 10 cm of soil and
reserve, sealed within a large
zip-closure bag within bowl B.

STEP 7: Carefully obtain a volumetric sample
with the Madera sampler. Place this
in a soil can.

STEP 8: Core to 5 cm below the intended point
of psychrometer installation and also
reserve with the sample in bowl B.

STEP 9: Thoroughly mix the contents of
bowl B. Fill a soil can (to the
extent permitted by the bag liners)
with a subsample of bowl B. Seal the
sample within a small zip-closure
plastic bag, place the lid on the
can, seal the can lid with electrical
tape, and pack in an insulated cooler
for the trip to the lab.

STEP 10: Partially back fill the hole with a small portion of the contents from bowl B, and lower the psychrometer cassette into place. Gently impress the psychrometers into place with minimal, gentle, back-and-forth twisting motions.

STEP 11: Back fill remaining contents of bowl B evenly around the cassette shaft. Gently rock the cassette shaft butt, pressing downward gently at the same time.

STEP 12: Back fill the hole with contents of bowl A. Again, gently rock the cassette while pressing downward.

STEP 13: Pour about 1 liter of clay slurry down the hole for sealing against vapor migration or downward water percolation.

STEP 14: Back fill the remainder of the hole with soil reserved adjacent to the hole.

STEP 15: Process the soil samples in the laboratory to obtain the water potential and water content of the sample obtained in Step 9, and the dry bulk density from Step 7.

FIGURE III.F.1.a

Figure 1.
Psychrometer
Cassette
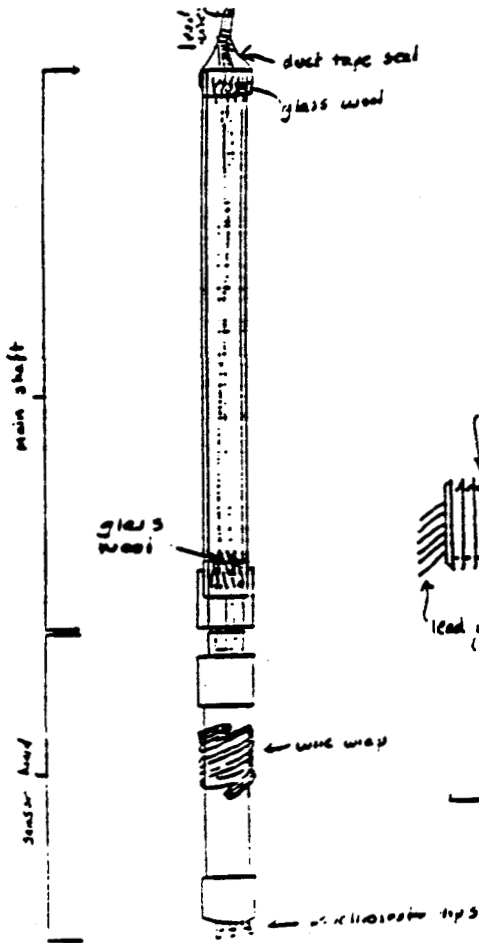
Figure 2. Psychrometer
Cassette - Sensor Head
same for all devices
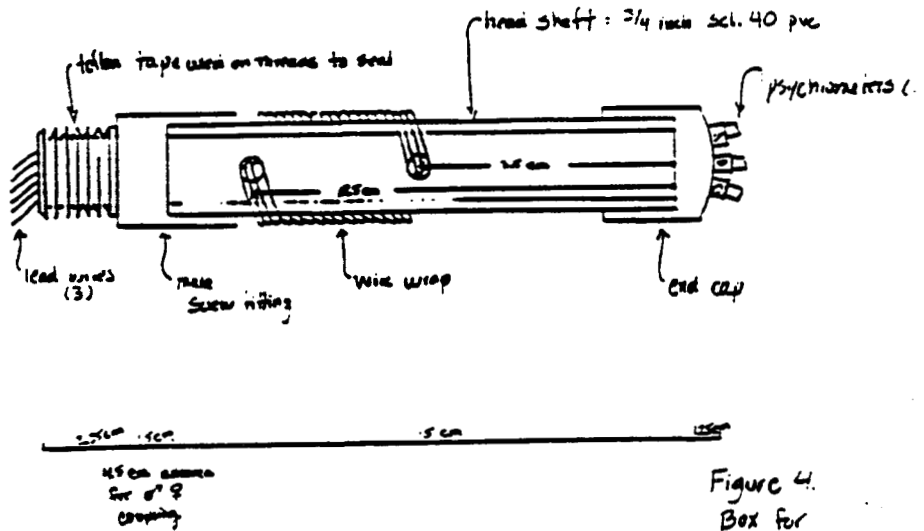
Figure 4.
Box for
psychrometer
cassette
protection
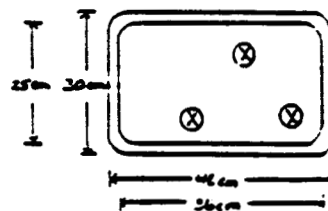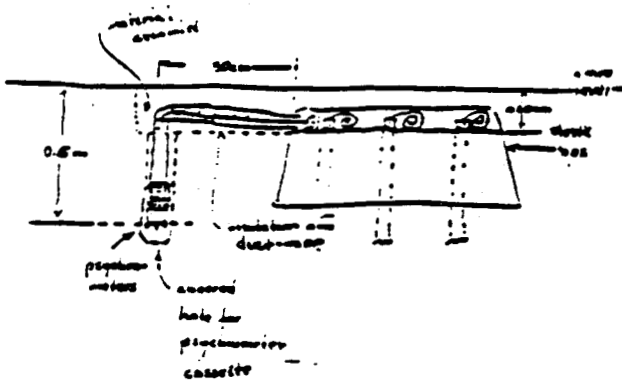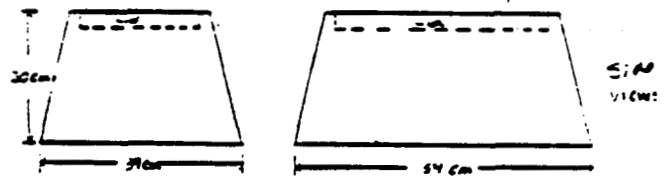
top view

⊗ psychrometer cassette

vi. Although factory calibration is per-
     formed for psychrometers, each psychro-
     meter will be recalibrated prior to
     incorporation into a cassette. This is
     performed to double check correct opera-
     tion and to confirm that the sensor tips
     are water tight. Psychrometer calibra-
     tion records will be kept to track each
     psychrometer through its useful life.
     Psychrometer calibration is described
     within Box III.F.1.a.vi.

BOX III.F.1.a.vi

PSYCHROMETER CALIBRATION

STEP 1: Mix a 0.5 molal solution of NaCl in
         distilled water according to
         specification in Bulletin 484 of the
         Utah Agricultural Experiment Station.

STEP 2: Seal psychrometers within glass
         bottles filled with the NaCl solution.

STEP 3: Place the sealed glass bottles within
         a water bath (necks of the bottles not
         submerged) within an insulated cooler.

STEP 4: Close the cooler with the wire leads
         protruding to access microvoltmeter
         measurements for the psychrometers.

STEP 5: Seal around the access holes for the
         wire leads.

STEP 6: Place the cooler containing water bath
         and the instrumented bottles within an
         environment which does not have more
         than 3° Celsius diurnal change of
         temperature for 12 to 24 hours to
         allow complete equilibration of the
         system.

STEP 7: Obtain microvolt readings of the psychrometers and record the zero-offset (measure of the temperature gradients in the system) and temperature.

STEP 8: Calculate the constant "gamma" in bars/microvolt to calibrate microvolt readings to interpret water potential. This calculation requires correcting the water potential of the solution for temperature using the following formula (Wescor, undated):

Corrected reading = Reading / (0.325 + 0.027T)

where T = ° Celsius

---

   vii. Psychrometer readings are taken according to the manufacturer's procedures. Psychrometer readings are corrected for temperature and then multiplied by the calibration factor (obtained as described above) for conversion into water potential.

b. The neutron probe will be used in a qualitative manner to inspect the relative soil water content in the profile between the depths at which the psychrometers are installed.

c. Piezometers extending to a depth of at least 10 m will be installed at each monitoring site to access and measure the water table. The method of installation when closer than 50 m to the vegetation transect or soil water instruments will be by augering. If implanted by jetting, piezometers will not be placed closer than 50 m to any point for measurement of soil

water or vegetation, and any surplus water from
the jetting will not be permitted to flow
toward the monitoring areas. The piezometers
will be located as close as possible to the
monitoring site, but outside possible influence
from ditches, irrigation, or other factors
which may affect water table levels.

2. Soil water content is calculated from the soil
    water potential measurements by a procedure which
    uses a family of characteristic curves. The
    technique is described in Box III.F.2.

BOX III.F.2

A FAMILY OF CHARACTERISTIC CURVES FOR MINERAL SOILS
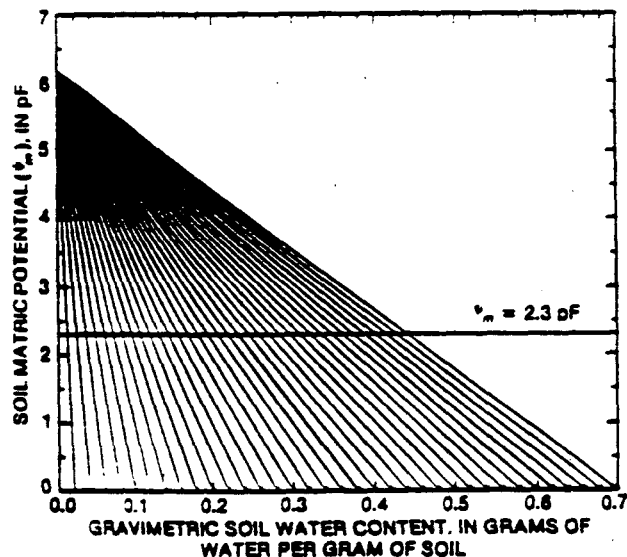
The above graph presents a soil water characteristics
model which relates soil pF to the weight-fraction soil
water content as presented in Sorenson and others
(1989). The application of these curves for

interpretation of soil water content is the "Miller Method." Toward the left side of the graph, the slopes indicate a rapid change of soil water potential from only a slight decrease in soil water content. This corresponds to coarse-textured soils, such as gravelly sands. Clayey textured soils, found toward the right-hand side of the graph, yield much greater amounts of water for each unit decrease of pF. A quadratic formula (Sorenson and others, 1989) may be used to calculate intercept and slope values which describe the curve for each soil:

$$Xint = \frac{-(B - \psi_m - (XM)(\theta_g)) + \sqrt{(B - \psi_m - (XM)(\theta_g))^2 - 4(XM)(-B)(\theta_g)}}{2(XM)}$$

$$Yint = XM(Xint) + B$$

where: B is 5.56 (a constant derived by
        Sorenson and others, 1989)

        XM is 0.888 (a constant derived by
        Sorenson and others, 1989)

        θ_g is the gravimetric soil water content,
        in grams of water per gram of soil
        measured on a sample obtained from the
        field

        ψ_m is the matric potential, in pF, measured
        on a sample obtained from the field

---

3. Each soil slice at each monitoring site will be calibrated to enable using the Miller Method. This procedure will be run either upon installation, or when the soil horizon reaches sufficient dryness to apply the method.

    a. Soil samples from psychrometer installation (see Box III.F.1.a.v, Step 9) are used to calibrate soils according to the Miller Method. For periodic monitoring, soil water content on a weight basis will be calculated from the psychrometric measurements using the curve

obtained for that soil horizon during the
Miller Method calibration.

     i.   The water potential of the soil sample
          for calibration will be determined under
          constant temperature conditions in the
          laboratory using replicate psychrometer
          measurements (n=3). The soil sample and
          psychrometer system will be thoroughly
          equilibrated within a cooler to prevent
          temperature gradients from influencing
          the measurements. This method is
          described in Box III.F.3.a.i.

BOX III.F.3.a.i

MILLER METHOD CALIBRATION

STEP 1: Unseal the soil can lid containing the
soil sample from Step 9 of
Box III.E.1.a.v.

STEP 2: Replace the can lid with a lid through
which three soil psychrometers have
been passed. Bury the psychrometers
in three separate locations toward the
center of the soil mass.

STEP 3: Reseal the zip-closure plastic bag and
reinforce the bag with electrical tape
around the exiting leads of the
psychrometers.

STEP 4: Reseal around the soil can with elec-
trical tape.

STEP 5: Place the instrumented soil can into a
double-insulated cooler which also con-
tains urethane foam placed to prevent
free air movement.

STEP 6: Pack urethane foam around the
psychrometer leads where they exit the
cooler box.

STEP 7: Place the cooler in an incubator or in
an environment with a diurnal
temperature fluctuation of no more
than 3° Celsius, and obtain readings
after 12 to 24 hours of equilibration.

STEP 8: Correct the microvolt readings for
temperature and calculate the water
potential for each soil sample using
the calibration-generated constant
"gamma."

STEP 9: Determine the average value for water
potential using the data generated by
the three psychrometers.

---

ii. Following measurement of soil water
potential, the weight water content of
the calibration sample will be deter-
mined gravimetrically for the same soil
mass.

iii. Slopes and y-intercept values describing
a soil water characteristic function
will be calculated from the paired water
potential, and content determined for
each soil slice during calibration. The
slopes and intercepts will be calculated
according to formulae provided in
Sorenson and others (1989), as shown in
Box III.F.2.

b. Volumetric soil water content is needed by the
monitoring system in order to project the
available water. This is calculated from
weight water content using the bulk density
determined following psychrometers implant.

$$\Theta_T = \rho_b \, \Theta_v$$

where Θ_T = water content
by volume
ρ_b = bulk density
Θ_v = water content
by weight

Bulk density will be determined for the depth
of the implanted psychrometers by obtaining a
volumetric soil sample (Step 7 of
Box III.F.1.a.v). The bulk density will be
calculated using the sample dry weight that has
been determined following over drying at 110°
Celsius.

4. Measuring Soil Water Potential in the Field

Psychrometer and piezometer measurements will be
collected monthly.

a. Psychrometers at each monitoring site will be
read monthly and these data will be used to
calculate soil water potential, weight and
volumetric water content, and available soil
water.

i. The psychrometer data will be screened
following each measurement to determine
if the sensors are malfunctioning and to
eliminate any aberrant data from the
records used to project plant-available
soil water. A technique for screening
psychrometer data is described in
Box III.F.4.a.i.

BOX III.F.4.a.i

SCREENING PSYCHROMETER DATA

Under field conditions, soil psychrometers occasionally malfunction. Three sensors were implanted at each depth to provide backup, as well as to provide the statistic that would permit detection of aberrant data. The data base accumulated during the first nine months of monitoring was analyzed to determine the coefficient of variance (cv) for the mean of triplets of psychrometers. A relationship between maximum observed cv was fitted as an exponential relationship to mean water potential. The curve with the least error was chosen as the relationship to screen the data. This curve was obtained using December 1988 monitoring data and represents the most stringent existing relationship for screening the psychrometer data. All of the monthly monitoring data must be screened following these steps:

STEP 1: Calculate the mean and standard deviation for each of the psychrometer triplets. These data are the water potentials of the field soils corrected for temperature.

STEP 2: Calculate the cv by dividing the standard deviation by the mean and multiplying the result by 100.

STEP 3: Compare the cv for each psychrometer triplet to the selected curve (the December curve) using the mean water potential as input. If the cv is less than the December curve, then the program accepts all three psychrometers. If the cv for the water potential measurement is greater than the December curve, the program drops the psychrometer datum which has the greatest absolute error from the mean.

The curve selected to screen the data is:

$$cv = e^{(3.45+0.0541*\text{mean water potential in bars})}$$

ii. At least two properly functioning
psychrometers will be maintained at each
monitoring depth at each monitoring
site. When less than two psychrometers
are judged to be functional, the
cassette will be replaced within two
months.

b. The depth to water in each piezometer located
at each monitoring site will be read on the
same day that the psychrometers are read.

The recorded depth to water will be made with
reference to the ground level unless otherwise
noted.

c. Neutron probe data are being collected to
provide a base for future statistical analyses
of soil water content. Neutron probe readings
will be taken at least during the months of
March, June, and October, but may be obtained
more often if necessary. Readings will be
taken every 10 cm down the soil profile.

G. Projecting Seasonal Water Balances for Plant Available
Soil Water and Transpiration Requirements

The ultimate objective for soil water monitoring is to
determine the amount of plant-available soil water.
For this comparison, plant water requirements projected
in Section III.E are compared to plant-available soil
water that is calculated in this section, using the
soil-water relationships and techniques presented in
Section III.F.

Knowing the tolerance ranges of the species occurring
on the monitoring sites is crucial to the ability to
predict plant responses to dry conditions. For each
species, the soil water potential (which limits the
plant's survivability) must be determined experi-
mentally. A number of techniques exist for such
experiments, some of which have been applied during the
Cooperative Studies. Limiting soil water potentials
obtained from previous experiments, such as Dileanis
and Groeneveld (1989), are being utilized to establish
the limits currently in use. The limiting water
potential can be converted to soil water content. The
soil water that is present in excess of the limit is
taken to be water available for plant consumption.

The distribution of root density and the maximal depth
of root growth are important considerations for pro-
jecting plant-water availability. Roots of Owens
Valley species have been found to decrease exponen-
tially with depth (Groeneveld, 1986), and to also have
a mathematically predictable maximum effective depth.
The findings from this work have been used to interpret
field data to derive empirical relationships that
(1) adjust the limiting water potentials with depth,
and (2) establish a depth limit for maximum effective
rooting, below which soil water is unavailable.

1. Establishing Absolute Limits for Soil Water
    Potential

    Each of the abundant perennial plant species at the
    monitoring sites will have their absolute limiting
    soil water potentials determined under laboratory
    conditions. This limit establishes the lowermost
    water potential below which a plant cannot extract

soil water. It may be determined by either of two
techniques.

a. Gradual Soil Drying

This technique is performed under controlled
conditions in a greenhouse. Replicate speci-
mens of each species are grown in pots equipped
with soil psychrometers implanted within the
root mass. The pots are sealed inside plastic
bags so that the only escape for water is via
transpiration. The bags are opened periodi-
cally to provide oxygen for root respiration.
The soil water potential is evaluated as the
plant gradually succumbs to water stress. The
absolute limit is reached when the soil water
potential has reached a plateau contemporarily
with the death of the plant.

b. Pressure Volume Curve

This technique follows descriptions in Dileanis
and Groeneveld (1989) and requires the
establishment of a pressure-volume curve for
each sample evaluated (Richter, 1978); Tyree
and Hammel, 1972). The plant material will
consist of shoots of each species gathered
before dawn. Initial osmotic potential and
initial pressure potential are extrapolated
from the pressure-volume curve for each
sample. These values are then plotted to yield
a lower limiting water potential curve.

2. The best available absolute limiting water poten-
tials for five species which inhabit the Valley

floor are presented in Table III.G.2. These data
were generated by gradual drying in a greenhouse
environment with methods which differed from those
noted in Section III.G.1.a above, and by
pressure-volume curve techniques as described in
Dileanis and Groeneveld (1989).

TABLE III.G.2

ABSOLUTE LIMITING WATER POTENTIALS
ESTABLISHED FOR FIVE VALLEY-FLOOR SPECIES
(Inyo County Water Department, data on file)

SPECIES	LIMITING pF	EQUIVALENT POTENTIAL (MPa)	SOURCE
Atriplex torreyi	4.66	-4.5	(1)
	4.71	-5.0	(2)
Chrysothamnus nauseosus	4.41	-2.5	(1)
	4.44	-2.7	(2)
Sarcobatus vermiculatus	4.66	-4.5	(1)
Artemisia tridentata	4.46	-2.8	(1)
Distichlis spicata	4.68	-4.7	(2)

(1) pressure-volume curves
(2) gradual drying

---

3. Pending further research, two limiting values of
    water potential have been adopted using the data
    from Table III.G.2. These limits are presented in
    Table III.G.3. A study is presently under way (as
    of April 1990) to test existing limits for known

species, or to establish these limits for new
species, using the gradual drying method. Eight
species will be studied: Atriplex torreyi,
A. canescens, A. confertifolia, Artemisia
tridentata, Sarcobatus vermiculatus,
Chrysothamnus nauseosus, Distichlis spicata,
and Sporobolus airoides.

TABLE III.G.3

LIMITING VALUES FOR SOIL WATER ABSORPTION
BY OWENS VALLEY-FLOOR SPECIES

Limit 1   -- pF = 4.4 --

           for Asteraceae shrubs
              Chrysothamnus nauseous
              Artemisia tridentata

Limits 2 and 3   -- pF = 4.7 --

           for Chenopod shrubs and the two
           abundant Owens Valley grasses
              Atriplex torreyi
              Sarcobatus vermiculatus
              Distichlis spicata
              Sporobolus airoides

---

4.   The Role of Rooting for Soil Water Extraction

     Depth and density of rooting are important for
     determining the available soil water and maximal
     depth for water extraction. (Note: Additional
     rooting data is under analysis at this time; there-
     fore, relationships presented here are subject to
     revision.)

a. Maximum effective depth of rooting (MED) will
    be determined for shrubs and grasses, sepa-
    rately, using field studies on sites where the
    water table has been drawn down by pumping.
    The MED will be determined by statistically
    modeling root density (length per unit volume)
    versus depth using the data from volumetric
    samples extracted by augering. The concept for
    MED is that even though root growth may occur
    below this depth, because of limited density,
    the role for uptake may be negligible. Best
    available information (per April 1990)
    indicates that MED for shrubs is 3.7 m and for
    grasses, around 2 m. Therefore, the top two
    meters has been chosen to be the rooting domain
    for grasses, and four-meters deep has been
    chosen for shrubs.

    Figure III.G.4.a presents a graphic representa-
    tion of the technique for determining MED on
    shrub species. For interpreting MED, future
    work will also attempt to correlate root
    density with the depthwise curve of pF.
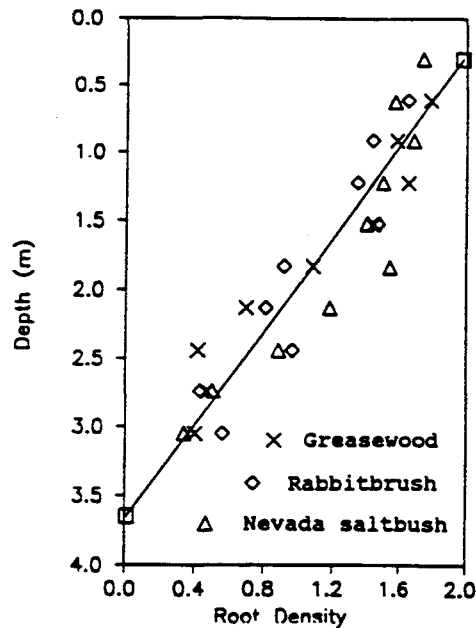
FIGURE III.G.4.a

Graph showing log-linear decrease of root density
with depth. These data were obtained at a study
location near Independence during January 1987 for
the Cooperative Studies. The water table had been
artificially lowered from about 1 m deep to approx-
imately 5 m deep over the previous three years.
From this data, the maximum effective rooting depth
(MED) is at 3.7 m, where the line crosses the
y-axis.

---

b. For Owens Valley-floor plant species, root
density has been found to decrease with depth
as an exponential function. Because the
hydraulic conductivity of soil decreases expo-
nentially as soil water content diminishes, the
decreasing root density with depth prevents
extraction of the water in the bulk soil down
to the absolute limit. The actual amount that
can be extracted can be determined empirically
as a function of root distribution with depth.
Existing data provided a relationship for
decrementing the limiting pF for each meter

slice of soil (see Figure III.G.4.b). The
depthwise values for limits one, two, and three
decremented using this relationship are
presented in Table III.G.4.b.
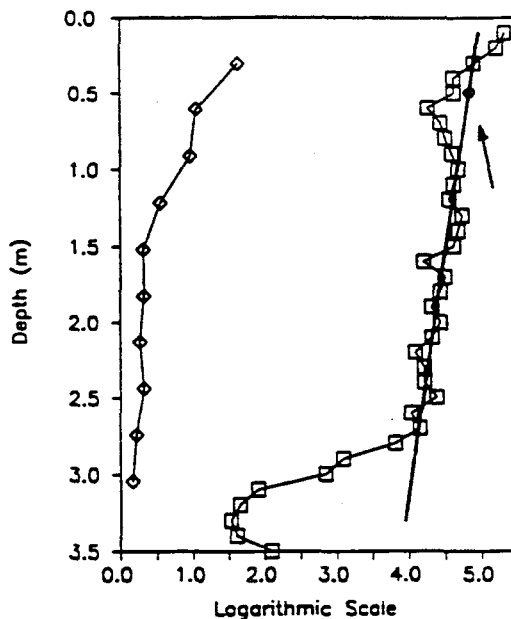
FIGURE III.G.4.b

Relationship used for decrementing soil water limits
with depth. On the graph are plotted depthwise
distribution of limiting water potential (as pF)
expressed as squares and root density expressed as
diamonds. The data were obtained at a study
location near Bishop which had the water table
artificially lowered during the previous 3 years.
The line that is superimposed on the pF data has
been used for decrementing limiting pF with depth.
The point indicated by the arrow is Limit 2 (pF of
4.7) which corresponds to the dominant vegetation
growing at the location. The lower pF values deeper
in the profile correspond to capillarity from the
water table at 3.7 m.

TABLE III.G.4.b

DEPTHWISE VALUES FOR LIMITS 1 AND 2
DECREMENTED BY
THE RELATIONSHIP IN FIGURE III.G.4.b

DEPTH SLICE	LIMIT 1 pF	LIMIT 1 MPa	LIMIT 2 pF	LIMIT 2 MPa	LIMIT 3 pF	LIMIT 3 MPa
1 m	4.4	-2.45	4.7	-4.90	4.7	-4.90
2 m	4.1	-1.23	4.4	-2.46	4.4	-2.46
3 m	3.9	-0.78	4.2	-1.55	-	-
4 m	3.6	-0.39	4.0	-0.99	-	-

5. Calculating the Plant-available Soil Water Content
    (abbreviated AWC)

    AWC is calculated at monitoring sites to project
    the soil-to-plant water balance.

    a. The AWC at each monitoring site shall be pro-
        jected for the dominant and co-dominant cover.
        Because all of the plants on a site are sharing
        the same soil water, transpiration from all
        species shall be projected at the limiting
        water potentials appropriate for the most
        sensitive dominant and/or co-dominant species.

b. Determining Limiting Water Content (LWC)

The "Miller Method" will be used to calculate
the LWC on a weight basis according to the
depthwise limiting soil water potentials. The
"Miller Method" calibration data will be used
for this calculation. To perform this
calculation, the slope and y-intercept of the
line determined during calibration
(Sections III.F.2 and III.F.3) are used to
calculate the water content for the appropriate
depthwise limit as presented in Table III.G.4.b.

$$\Theta_{w} = \frac{a - pFlim}{b}$$

where: pFlim = limiting pF
         b = slope
         a = y intercept

c. The AWC will be computed on a per-meter
depth-slice basis to compare the limiting water
contents by the Miller Curve technique for each
meter slice of soil.

$$\Theta_{AWC} = \frac{a - pFmeasured}{b}$$

where pF measured = value calculated
                     from monthly reading

The depthwise limiting water potentials will be used to calculate a limiting weight water content for each meter slice which will be subtracted from the weight water content calculated using the characteristic function and data obtained from the in situ psychrometers. For the purpose of monitoring and estimation, the result of this calculation is taken as representative of the available water for the 1 m slice of soil in which the psychrometers reside. The calculation is shown graphically in Figure III.G.5.c.
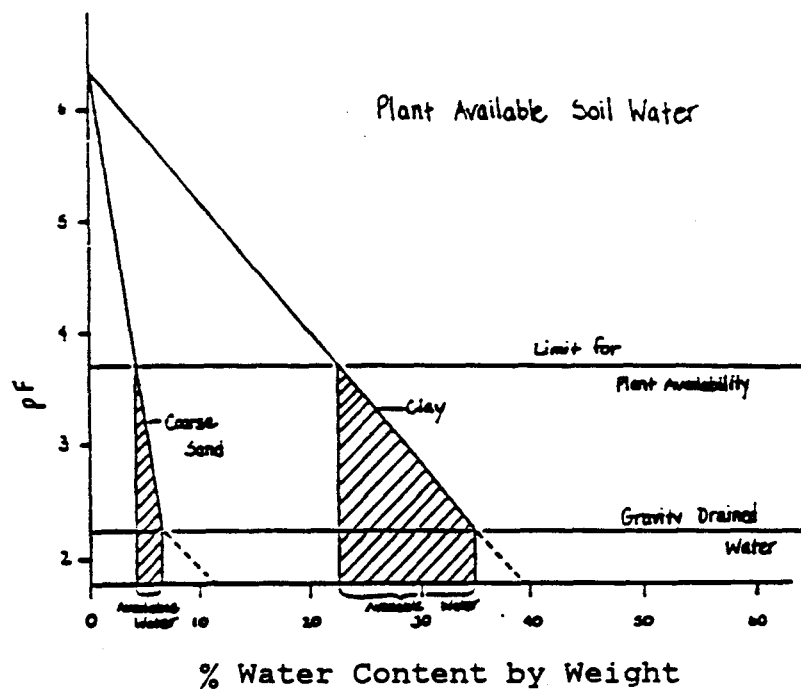
FIGURE III.G.5.c

Graph depicting the use of the "Miller Method" for calculating plant-available water. The plant-available limit was set at pF = 3.7 for this example. The calibration procedure sets the linear relationship to be used for the characteristic function, and the plant limit sets the upper bound along the line. Soil water contents measured in

the field along any point on the line below the
limiting value describe the plant-available water
in that soil slice. Note that coarse-textured
soils yield much less water for a given change in
pF than do finer-textured soils.

---

d. Volumetric soil water content will be calcu-
    lated from the weight water content by multi-
    plying by the bulk density obtained during
    calibration as described under III.F.3.b.

e. The AWC will be determined by summing the
    individual AWC for the meter-slices of soil
    representing the appropriate rooting zone. For
    grasses, this will be the upper two meters.
    For shrubs, this will be 4.0 meters deep. This
    is under analysis.

6. Projecting the Water Balance for the Vegetation
    Through a Growing Season

    The species-wise transpiration curves combined with
    leaf area will be used to project transpiration for
    a full or partial growing season
    (Section III.D.1.c). This plant requirement is
    then subtracted from the available soil water
    computed as the sum for all depth slices within the
    rooting zone. Precipitation is incremented to
    available soil water for projecting soil-to-plant
    water balance according to the Agreement.

    a. For projecting the soil-to-plant water balance
        for the following growing season using March
        psychrometric data, estimates of plant-water
        requirements will be based on vegetation data
        collected during the previous growing season.

No precipitation will be incremented to the calculation of water balance when made for the growing season during the same calendar year.

b. When projecting the soil-to-plant water balance for the remainder of the growing season, the most current vegetation measurements will be used and the integration of the linked poly-nomial curves will be between the times taken to represent the mid-season peak (DOY is 186) and leaf drop (DOY is 289). The resultant plant-water requirement will be compared to the estimation of available water. No precipitation will be incremented to the calculation.

c. For soil-to-plant water balance projections made during October for the following growing season, plant-water requirements will be apportioned by the curves which governed plant-water requirements through the summer growing season just completed. The AWC for this calculation will be the AWC from the most current psychrometer readings, with an increment added to represent half of the average annual precipitation. The precipita-tion amount used is the quadrangle average precipitation from isohyetal maps (LADWP, 1976). The one-half precipitation figure represents the amount of water projected to be available to plants since approximately half of the average annual precipitation is lost through evaporation (Groeneveld, 1989).

    The amount of precipitation that is credited to the October calculations will be reduced during

periods of drought according to the scheme shown in Table III.G.6.c.

TABLE III.G.6.c

SCHEME FOR DECREMENTING
ADDED PRECIPITATION DURING DROUGHT PERIODS

ADDED PRECIPITATION	CONDITIONS
40%	If the previous year's run-off and current year's projection are less than 70% of average
30%	If the two previous year's runoff and the forecasted runoff are less than 75% of average

---

IV. HYDROLOGIC MANAGEMENT

This section outlines the procedures that will be followed
in the monitoring and evaluation of hydrologic data.
Effects on private wells, the procedures for locating and
operating new wells, and the methods of determining ground-
water mining are described. Prior to presenting the
specific issues contained in this section, some of the
basic techniques of hydrologic analysis are discussed.

The hydrologic data that will be analyzed by both LADWP and
Inyo County include depth to water data in approximately
700 monitoring wells; water levels and pumping data in
approximately 100 pump-equipped wells; flow data from
various streams and canals; precipitation data; and water
use data on LADWP-owned land. Most of these data are
collected monthly. Some depth-to-water data is collected
less frequently--especially outside of well fields--but it
is collected at least twice per year. Historical hydro-
logic data that has been collected by LADWP is contained in
reports entitled "Monthly Well Report" and "Totals and
Means Report."

Some of these basic data will be summarized in the form of
hydrographs (time series plots of the data) in order to
regularly identify trends and evaluate conditions qualita-
tively. More detailed, quantitative analyses of portions
of the data will be performed under certain specific
conditions described below. Independent quantitative
analyses will also be performed by either the County or
LADWP as conditions or circumstances warrant.

Specific techniques are sometimes used in an attempt to
analyze and quantify a cause-and-effect relationship that
has been inferred from a qualitative evaluation of the data
(i.e., a trend is observed in the data that corresponds to

an identified cause). For example, the decline in the water level in a well can be caused by groundwater pumping, by decreased recharge to an area, or by both. Therefore, the qualitative interpretation of a hydrograph that shows a declining water level during a period of high pumping and low recharge is that both factors are affecting the water level in the well. Quantitative analysis is necessary to separate the effects of the individual causes. Three types of commonly used quantitative analysis are briefly described in this section: regression analysis, analytical modeling, and numerical modeling.

Regression analysis relies on the defining of the process under investigation through a statistical analysis of the data. The result of a regression analysis of groundwater levels in a specific well would provide an equation that predicts the groundwater level in a specific well, given the pumping and recharge in a given well field. One result of this type of equation is the ability to separate the effects of drought and pumping. Regression analysis is a tool that should be used cautiously due to its empirical nature.

Analytical and numerical modeling of a hydrologic system represents a physically based approach to analyze and quantify cause-and-effect relationships. Both techniques rely on physically based equations that mathematically describe groundwater flow. The results of these approaches include estimates of groundwater level, change in ground-water level (drawdown or recovery without regard to specific starting or ending level), and flow (either as spring flow or subsurface flow). Basic input to either approach includes numerical values that describe the aquifer system (e.g., transmissivity, storativity, leakance), quantification of recharge and pumping, and

mathematically describing the boundary conditions of the flow system under investigation.

The basic difference between analytical and numerical modeling is in the types of assumptions that are necessary to describe the hydrologic system in terms of mathematical equations. In general, while analytical methods are more easily implemented, they are also more restrictive, in terms of simplifying assumptions, than are numerical methods. The decision to choose one method over the other is generally based on data availability (numerical models require large amounts of data), and on the type of analysis (simple versus complex relationships). Analytical methods are generally better suited to investigations of relatively simple relationships (e.g., predicting the drawdown in a well due to the pumping of a limited number of wells at a constant rate), while numerical methods are better suited to investigating complex relationships (e.g., the regional response of water levels under varying amounts of pumping and recharge). In all instances, at least some input data must be estimated, and the results interpreted in light of the assumptions and limitations of the particular modeling approach.

The most notable example of an application of numerical techniques in the Owens Valley, to date, and one of the principal tools that will be used in the future for hydrologic analyses, is the groundwater flow models that have been developed by the U.S. Geological Survey, Inyo County, and LADWP. These models were developed and calibrated as part of the groundwater studies from 1985 to 1988, and represent the most comprehensive description of the hydrologic system of the Owens Valley. The U.S. Geological Survey model covers the entire Valley, the northern half of the Valley was modeled by Inyo, and the southern half was modeled by LADWP. All models were

developed in conjunction with the others and, where the
areas overlap, all provide similar results. Details of the
models are contained in reports that are available at the
Inyo County Water Department and LADWP offices.

The Inyo and LADWP models were used to develop the 10-foot
drawdown contours that are depicted on the vegetation
management maps. These contours were developed by running
the models under assumed worst-case scenario conditions
(all existing wells pumping with recharge conditions of
April 1977 to March 1978 repeated three consecutive
years). The area within the contours represents the area
that could potentially be impacted by pumping, and
vegetation soil monitoring networks were subsequently
established partially on the basis of these results.

A. Private Wells

Monitoring to protect private wells will be conducted
at existing and/or newly installed monitoring wells.
The data from these monitoring wells, along with other
hydrologic analyses, will be used to attempt to
separate the effects of drought, private pumping, and
LADWP pumping on groundwater levels.

Shallow monitoring wells will be installed in the
Valley as necessary to determine whether groundwater
pumping by LADWP will affect water levels in private
wells.

1. Determining whether an impact on a private well is
    attributable to groundwater pumping by LADWP.

    Hydrologic analyses will be conducted to determine
    whether the lowering of the water level in a

private well is attributable to groundwater pumping by LADWP. These analyses will include the performance of aquifer tests where necessary, site-specific analytical or numerical modeling, and running the groundwater flow model of the area in question. Due to the inherent assumptions and limitations of the groundwater models, they will be used only to identify areas of potential concern. The models were developed to evaluate long-term and regional effects of pumping. Private wells were not included in the models because of the cyclic nature of their operation and their generally low production rates. Therefore, groundwater models will be used to identify potential areas of concern and more site-specific techniques will be applied, such as installation of monitoring wells, to project and avoid potential problems.

a. Aquifer tests will be conducted at all LADWP wells located near private wells if sufficient aquifer characteristic data do not already exist for the area.

b. The Technical Group will initiate site-specific analytical or numerical models to evaluate the response of private wells to pumping and drought. Groundwater levels will be measured at monitoring wells drilled to depths similar to the nearby private wells. The data collected from these sites will be used to track the response of groundwater levels in the area due to the effects of drought, private pumping, and LADWP pumping.

2. Determining whether an impact on a private well is significant.

    In determining if increased pumping by LADWP is causing a significant impact on private wells, the following factors will be considered:

    a. Amount of water table decline attributable to LADWP pumping.

    b. Decreases in flow rates from private wells attributable to LADWP pumping.

    c. Amount of additional pump lift required as a result of water table lowering caused by LADWP pumping.

3. Mitigating impacts to private wells.

    Any significant impacts on private wells will be promptly mitigated by LADWP such that the impact is reduced to a less than significant level in a manner that is fair and equitable to the owner of the private well. Examples of mitigation include the following:

    a. Discontinue pumping LADWP wells to allow water level recovery in the vicinity of the impacted private well.

    b. Setting the pump deeper in the casing of the private well.

    c. Deepening or replacing the private well.

d. Compensation for additional power cost if water table decline requires significant increase in pump lift.

B. Guidelines for Drilling and Activating New Production Wells

As provided in Section VI of the Agreement, the Department may replace existing wells and construct new wells in areas where hydrogeologic conditions are favorable, and where the operation of the wells will not cause a significant change in vegetation that would be inconsistent with the goals and principles of the Agreement. The guidelines that will be followed when constructing and putting new wells into operation are set forth in this section.

1. Evaluation of Potential Impacts

The potential impact of operating new wells will be evaluated by the Inyo/Los Angeles Technical Group as follows:

a. Developing information on the hydrogeologic conditions at the site by:

i. Reviewing existing nearby well logs, borehole logs, well test reports, water level data, and pumping data.

ii. If available, running the appropriate groundwater flow model with all existing wells and the new well(s) pumping during a simulated worst-case, three-year drought (hydrologic conditions of runoff

year 1977-78, which is the driest on record, repeated three times) to identify the areas with the greatest potential for surface effects due to pumping (area of 10 feet or greater drawdown).

    iii. Drilling one or more test holes if water level data is not adequate or not available.

b. Inventorying and classifying the vegetation that could be affected by operation of the well (use vegetation inventories that reflect conditions from 1984 to 1987).

    i. Identifying vegetation that has the greatest chance of being adversely impacted by pumping (the area where drawdown is greater than or equal to 10 feet).

    ii. Identifying new sites for monitoring vegetation, soil moisture, and water level as necessary.

c. Identification and assessment of other potential significant effects on the environment:

    i. Springs (e.g., reduced flow resulting in significantly less water available to surrounding vegetation).

    ii. Flowing wells (e.g., reduced flow resulting in significantly less water available to surrounding vegetation).

iii. Private wells (e.g., lowered water
levels resulting in significantly
increased pumping costs and/or impair-
ment of operation).

2. Construction and Testing

a. LADWP will design, schedule, and contract for
optimally designed wells considering location,
economics, and current practice in the industry.

b. Inyo County shall apply for and obtain any well
construction permits required by the County.

c. Aquifer test:

i. A constant flow rate aquifer test (up to
72 hours duration) will be conducted on
each new well. The Technical Group will
determine the length of the aquifer test.

ii. A minimum of one monitoring well is
required for the test. The Technical
Group will determine whether existing
monitoring wells are adequate, or
whether there is a need to construct a
new monitoring well.

iii. All well and test data will be shared by
Inyo County and LADWP.

3. New Well Areas

a. Only one well shall initially be constructed
and operated in any new area.

b. Water levels and vegetation shall be monitored as agreed to by the Technical Group. Additional monitoring wells may be required.

c. Monitoring to evaluate for any potential effects of the operation of the new well or wells shall be performed. This may require installation of monitoring wells which will be constructed at the same time as the production well.

d. No additional well(s) shall be installed in the area until an initial well has been operated for at least six (6) months at full operational capacity.

C. Determining Existence of Groundwater Mining

One of the goals of the Inyo/Los Angeles Agreement on a Long-term Groundwater Management Plan is to avoid long-term groundwater mining in the Owens Valley. The method that has been established to meet this goal is management of groundwater pumping, so that the total pumping from any well field over a 20-year period (the current year plus the 19 previous years) does not exceed the total recharge to the same well field area over the same period. The Technical Group may increase the annual pumping from a well field area above this amount if a recharge program for that area is implemented, or for other relevant reasons that are consistent with the goals and principles of the Agreement.

1. Background and Definition

   This section of the Green Book presents information
   related to the general subject of groundwater
   mining; presents and discusses the definition of
   groundwater mining as used in the Agreement;
   presents the details of the recharge calculations
   that will be performed; discusses the concept of
   well field areas and how the calculated recharge is
   apportioned to the identified areas; and presents
   the procedures related to the management of ground-
   water pumping that will be used to ensure that
   pumping will not exceed recharge in accordance with
   the Agreement.

   The concept of groundwater mining is rather subjec-
   tive, and no consistent definition exists.
   J. H. Feth, of the U.S. Geological Survey (USGS),
   provides a description and review of the use of the
   term in an article that appeared in a USGS publi-
   cation (WRD Bulletin, January 1982, on file with
   the Inyo County Water Department). The article pro-
   vided a foundation that was used to develop a defi-
   nition for the Inyo/Los Angeles Agreement that was
   both technically accurate and acceptable to the
   public's desire to have a consistent definition
   that could be easily applied and understood, and
   that would prevent depletion of the groundwater
   resources of the Owens Valley.

   Feth's main point in the article is that the term
   "groundwater mining," if used, should be defined.
   The proposed Agreement provides such a definition
   by stating what is to be avoided: "managing annual
   groundwater pumping so that the total pumping from
   any well field over a 20-year period does not

exceed the total recharge to the same well field
area over the same 20-year period." Clearly, the
intent of the groundwater mining provision of the
proposed Agreement is to prevent long-term
depletion of groundwater storage.

Feth summarizes several definitions of groundwater
mining, many of which include the comparison of
pumping and recharge. Many of the definitions also
include the use of actual groundwater level data.
While it is not explicitly stated in the proposed
Agreement, the monitoring and interpretation of
groundwater level data in all wells is an important
aspect of protection of vegetation and of the
groundwater resource. Inherent difficulties in
application and interpretation of actual
groundwater level data prevents their effective use
with a "formula" approach to prevent groundwater
mining in the Owens Valley. The evaluation of
these data will serve as a check as to the accuracy
of the recharge estimates that have been and will
be made.

Avoidance of groundwater mining does not provide
protection to the vegetation. Provisions for vege-
tation protection are contained in other sections
of the Agreement. The intent of this provision is
to avoid long-term depletion of groundwater storage.

Storage is depleted any time a well is on, whether
the well belongs to DWP or a private domestic
user. Storage will be depleted to an even greater
extent when pumping continues during a drought
period. Storage is replenished, however, in a
short time period when the private domestic well is
turned off, and over a longer period when DWP turns

its wells off during wet years. As long as the
long-term pumping does not exceed the long-term
recharge, no mining is occurring.

Another point that needs to be emphasized is that
the definition that is included in the
Inyo/Los Angeles Agreement provides for the avoid-
ance of mining by requiring the adjustment of
pumping amounts if it is clear that pumping will
exceed recharge. The relatively simple formula
approach allows for an easy determination of this
possibility, and immediate steps to correct the
situation can be implemented before mining actually
is occurring.

In addition, it should be noted that the concept of
groundwater mining is distinct from the concept of
safe yield of a groundwater basin. The concept of
groundwater mining deals only with a permanent
depletion of storage of groundwater. The concept
of safe yield, however, involves factors and issues
that involve placing values--economic and
noneconomic--on either the use of groundwater (in
the case of the Owens Valley, for example, the use
by native vegetation versus pumping by export), or
the effects of groundwater development (in the case
of the Owens Valley, for example, the adverse
effects of DWP pumping on other groundwater users
in the Owens Valley). Per the Inyo/Los Angeles
Agreement, safe yield in the Owens Valley can be
defined as the amount of groundwater that can be
extracted without any adverse effect on the
environment or on other users of groundwater. It
can be seen that a given average amount of pumping
over several years could either result in impacts

or have no impacts depending upon how that ground-water was pumped, both spatially and temporally.

While the Inyo/Los Angeles Agreement does not establish a set quantity of pumping (except for the Bishop Cone), the environmental standards set forth define "safe yield." Indeed, it is commonly accepted among hydrologists that, given the myriad of competing values that are involved in defining a quantity of safe yield, a single average quantity cannot be adequately defined. The Inyo/Los Angeles Agreement is in accord with this accepted practice by placing more faith in monitoring data to dynamically define safe yield rather than establishing set amounts of pumping that would ostensibly prevent all undesirable effects.

2. Calculation of Groundwater Recharge

The current method used to compute a recharge value for each well field relies on information obtained from the USGS relevant to its computer model of the Owens Valley (Wes Danskin, written communication, 1989). Using water years (October to September) as the basis for calculations, yearly numerical values are obtained for each source of recharge to the aquifer system in the Owens Valley in each well field. The described method is illustrated herein using data for water years 1969 through 1989.

Eight sources are considered when calculating recharge in the Owens Valley. These are: streams, ungaged intermountain slopes, canals, groundwater recharge, underflow, irrigation and livestock, precipitation, and lakes and reservoirs. The following paragraphs explain the procedure for calculating the individual source values.

Streams

Recharge to groundwater occurring in each stream is
calculated as a function of gage readings, channel
characteristics, evaporation, and vegetative
covering by using equation (1) below:

(1):

$$R_{ij} = (BOM_i * RO_j * SRR_i) * (1 + SRA_i + SRB_i) - SL_i * SW_i * SET_i * VC_i$$

where:
- i = Stream index

- j = Year index

- R_{ij} = Recharge in stream i during year j $[L^3/T]$

- BOM_i = Average flow at base of mountain station for stream i (if no gage, represents where stream enters the Valley fill) $[L^3/T]$

- RO_j = Ratio of annual Valley-wide runoff to long-term average Valley-wide runoff for year j

- SRR_i = Ratio of stream loss to BOM_i for stream i

- SRA_i = Fractional increase in stream length above station for stream i

- SRB_i = Fractional increase in stream length below station for stream i

- SL_i = Length of stream i $[L]$

- SW_i = Width of stream i $[L]$

- SET_i = Annual evaporation from area near stream channel for stream i $[L/T]$

- VC_i = Fraction of area near stream channel covered by vegetation for stream i

Table 1 (Appendix B) provides the values for BOM,
SRR, SRA, SRB, SL, SW, SET, and VC for each stream

included in the analysis, while Table 2 (Appendix B) gives the
values for RO for water years 1969 through 1989. In addition,
Table 3 (Appendix B) provides the calculated stream recharge
values in acre feet per year for water years 1969 through 1989.

Ungaged Intermountain Slopes

Recharge to groundwater due to runoff that infil-
trates in areas without defined channels is cal-
culated using equation (2) below:

(2):

$$R_{ij} = UR_i * RO_j$$

where: i = Intermountain slope index

         j = Year index

R_{ij} = Recharge in intermountain slope area i
           in year j $[L^3/T]$

UR_i = Long-term average ungaged recharge for
          slope i $[L^3/T]$

RO_j = Ratio of annual Valley-wide runoff to
          long-term average Valley-wide runoff
          for year j

Table 4 (Appendix B) lists the UR values for each
ungaged intermountain slope included in the
analysis, while Table 5 (Appendix B) provides the
calculated recharge in acre feet per year for water
years 1969 through 1989.

Canals

Two categories of canal recharge--spillgates and
canals--are used. A time averaged value for each

canal component is used for each year it is in
use. For spillgates, the following equation (3) is
used:

(3):

$$R_{ij} = SGD_{ij} * SGR_i$$

where: i   =   Spillgate index

         j   =   Year index

       R_{ij} =   Recharge in spillgate area i in year j
                 $[L^3/T]$

       SGD_{ij} = Discharge at spillgate i in year j,
                 either an average annual or actual
                 annual value dependent upon j $[L^3/T]$

       SGR_i =   Average annual recharge rate in
                 spillgate area for spillgate i

Table 6 (Appendix B) lists the values for SGD and
SGR, as well as the calculated annual recharge rate
for each spillgate. Average annual values for SGD
are generated for water years 1969 through 1986,
while an actual annual SGD for each spillgate is
used beginning in water year 1987.

The canals considered have an estimated recharge
rate which remains constant for each year it is
active. Zero recharge occurs when a canal is not
in use. Equation (4) is used to determine recharge
by:

(4):

$$R_{ij} = \begin{cases} CR_i & \text{for } j \text{ in set } J_i \\ 0 & \text{for } j \text{ not in set } J_i \end{cases}$$

where: i   =   Canal index

$$j \quad = \quad \text{Year index}$$

$$J_i \quad = \quad \text{Set of years in which canal } i \text{ is in operation}$$

$$R_{ij} \quad = \quad \text{Recharge in canal } i \text{ in year } j \text{ [L}^3/\text{T]}$$

$$CR_i \quad = \quad \text{Average estimated canal recharge for canal } i \text{ [L}^3/\text{T]}$$

Table 7 (Appendix B) lists the values for CR, the years comprising set J, and the calculated recharge for each canal considered. In future years, an updating of set J based on the actual operation of the canals is required.

Groundwater Recharge Areas

Areas in which water is allocated for groundwater recharge are included in the calculations labeled under this section. There are three formulas used for calculation, one being the general format with two noted exceptions. For all but the two cases described below, recharge is calculated by using equation (5).

(5):

$$R_{ij} = RR_i * AL_i * LADWP_{ij}$$

where: $\quad i \quad = \quad$ Recharge area index

$$j \quad = \quad \text{Year index}$$

$$R_{ij} \quad = \quad \text{Recharge in area } i \text{ in year } j \text{ [L}^3/\text{T]}$$

$$RR_i \quad = \quad \text{Recharge rate for recharge area } i$$

$$AL_i \quad = \quad \text{Fraction of water allocated to area } i \text{ compared to total allocation}$$

$$LADWP_{ij} \quad = \quad \text{Estimated annual quantity of water allocated to general areas of Owens Valley for a particular use (see Russ Rawson of LADWP)}$$

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Table 8 (Appendix B) provides the values for RR, AL, and the applicable area used for LADWP for each recharge area. Table 9 (Appendix B) provides the values for LADWP for each area for water years 1971 through 1989. The computations leading to Table 9 (Appendix B) are not available prior to 1971; therefore, an alternative method was used to estimate the values for years 1969 and 1970 (see Wes Danskin of USGS).

For the Blackrock/Thibaut Areas 1, 2, and 3, equation (6), a modification of equation (5), is used, so that:

(6):

For RO_j greater than 1.25:

$$R_{ij} = RR_i*AL_i*MIN[MAX(0,LADWP_{ij}-C_1),C_2]$$

For RO_j less than or equal to 1.25:

$$R_{ij} = 0$$

where: C_1 = 6444 ac.ft.

C_2 = 50 cfs

RO_j = Ratio of annual Valley-wide runoff to long-term average Valley-wide runoff

MAX = Maximum function

MIN = Minimum function

R_{ij}, RR_i, AL_i, and $LADWP_{ij}$ are described in equation (5).

For Indian lands, equation (5) is reduced to equation (7) below:

(7):

$$R_{ij} = RR_i * LADWP_{ij}$$

where: R_{ij}, RR_i, and $LADWP_{ij}$ are described above
in equation (5)

Table 10 (Appendix B) provides the calculated
recharge values for water years 1969 through 1989
for each recharge area listed on Table 8
(Appendix B).

Underflow, Irrigation and Livestock, Precipitation,
Lakes and Reservoirs

Estimates for the average volume of recharge per
year for underflow, irrigation and livestock, pre-
cipitation, and lake and reservoir components were
obtained from the USGS Open-File Report 88-715,
1989. These values--averages based on water years
1970 through 1984--are as follows:

Underflow	4000 acre-feet per year
Irrigation and Livestock	10000 acre-feet per year
Precipitation	2000 acre-feet per year
Lake and Reservoir	1000 acre-feet per year

Once the well field areas have been delineated, the
values above are apportioned amongst them in an
appropriate fashion.

3. Calculation of Annual Recharge by Well Field Area

The following section describes the method used to
calculate the yearly recharge in the various Owens
Valley well field areas. Well field areas in the
Owens Valley have been designated on the basis of
an evaluation of groundwater flow patterns which
were derived from an analysis of groundwater level

data and the results of the groundwater flow models developed by LADWP and Inyo County. At present, six well field areas have been designated: Laws, Bishop, Big Pine, Taboose-Thibaut, Independence-Symmes-Bairs, and Lone Pine.

The northern portion of the Valley was considered as three distinct areas. Groundwater flow in the Bishop area is from west to east, curving to the south in response to the presence of the Owens River. Flow from Laws is from north to south. Big Pine is considered a separate area due to flow patterns, its isolation from the Bishop area, and its separation from the Taboose-Thibaut area by the Poverty Hills, which act as a barrier to ground-water flow.

The southern portion of the Valley is divided into three areas. The Taboose-Thibaut area covers the Taboose-Aberdeen and Thibaut-Sawmill well fields. The fact that these well fields are close together, have no natural hydrologic boundary separating them, and groundwater flow patterns between the well fields change in response to high pumping, suggest that these areas can be treated as one for the purposes of calculating recharge. Of note in this area is the allocation of 50 percent of Oak Creek recharge (stream and ungaged intermountain slope) to this area. High pumping during periods of low runoff and constant pumping at the Blackrock Fish Hatchery have caused a reversal in the pre-1970 gradient in the area south of the hatchery. This results in significant recharge from Oak Creek flowing north into the Thibaut-Sawmill area. Future analysis will attempt to more accurately quantify this component.

The Independence-Symmes-Bairs area covers the Independence-Oak, Symmes-Shepherd, and Bairs-Georges well fields. These well fields have been combined on the basis of groundwater flow patterns in the alluvial fan areas and the proximity of the well fields to one another. The northerly component of groundwater flow in the fan areas suggest that recharge from as far south as Georges Creek can recharge the Independence-Oak well field.

Lone Pine is considered a separate area due to the distance between the wells and the Bairs-Georges well field. In addition, the presence of the Alabama Hills effectively isolates the Lone Pine area.

A net recharge to groundwater for each designated well field area in the Owens Valley is computed by summing the individual components of each source contributing to that well field area. Table 11 (Appendix B) contains the assignment of recharge from streams, ungaged intermountain slopes, canals, and groundwater recharge areas to each well field area; divisions of underflow, irrigation and livestock, precipitation, and lakes and reservoirs among the well field areas are presented in Table 12 (Appendix B).

Using the above procedure for determining yearly recharge components to each well field area, a net recharge for each area was calculated for each water year in the time period bracketed by 1969 and 1989. Calculated values are given by well field area for water year 1989 in Table 13 (Appendix B). In these calculations, the assumption is made that

the average values remain as given above for
underflow, irrigation and livestock, precipitation,
and lakes and reservoirs. Total calculated
recharge by well field for each year indicated
above is given in Table 14 (Appendix B), along with
the yearly historical pumping values. The official
pumping records on a well field basis are found in
the LADWP's Monthly Well Report, Book A.

It should be recognized that the recharge estimates
and subzone delineations are developed for specific
years in 20-year periods. As pumping amounts and
patterns change, the amount of recharge and the
distribution of hydrologic subzones may change. It
will be necessary to analyze total recharge,
recharge components, water level changes, and
groundwater flow patterns in the future to deter-
mine recharge conditions for any future 20-year
period in order to determine whether or not
long-term groundwater mining is occurring.

4.   Procedures for Managing Annual Pumping

The annual pumping program, developed in April in
each year, provides a convenient vehicle to address
the issue of groundwater mining. The data (runoff,
water use, pumping, and groundwater level) for the
previous water year (October-September) are
complete and in their final form by December which
provides the Technical Group sufficient time to
thoroughly analyze the groundwater conditions of
the Valley, and recommend any necessary
modifications to the recharge calculations or well
field designations prior to implementing the
pumping program for the runoff year.

The use of estimated recharge values, based on runoff estimates for the previous October-March and estimated recharge values for the ensuing April-September period will be used to update the recharge/pumping comparisons into the future, and establish limits on the amount of pumping by well field areas in accordance with the provisions of the Agreement. The review and reporting period for the mining calculations and establishment of limits are, therefore, during the April pumping program.

As discussed previously, the calculation of recharge is a detailed and rigorous exercise. In order to facilitate the calculation in the context of estimating future recharge as part of establishing pumping limits, the use of relatively simple functional relationships between runoff and recharge, derived through regression analysis, will be used. These relationships are:

Laws	$455 + (0.976 * (RO**2)) + (387536/RO)$
Bishop	$16144 + (281 * RO)$
Big Pine	$584 + (284 * RO)$
Taboose-Thibaut	$1466 + (342 * RO)$
Ind-Sym-Bairs	$3475 + (347 * RO)$
Lone Pine	$3492 + (110 * RO)$

where: Recharge amounts in acre-feet/year
RO = Runoff in percent average
Average runoff = 469852 acre-feet/year
(calculated for the 49-year period from 1935 to 1984)

These regression equations will have to be reviewed
and changed periodically as new data becomes avail-
able to reflect changes in operations and well
field area boundaries, or the need for distribution
of percent average runoff.

The estimate of runoff for the entire Owens River
watershed (Long Valley, Long Valley to Tinemaha,
and Tinemaha to Haiwee) from the previous October
to March period, in acre-feet, will be added to the
projected April to September runoff, in acre-feet,
to arrive at an estimated October to September
runoff. This value will then be divided by 469,852
and multiplied by 100 to arrive at an estimate of
runoff in terms of percent of average. This
percent average value will then be entered into the
above regression equations to arrive at an esti-
mated recharge in each well field area. The fit of
these models to actual data are presented on
Figures 1 through 6 (Appendix B).

Based on this estimated recharge and the total
recharge during the previous 19 years, total
recharge for the 20-year period is calculated. The
actual pumping from the previous 19½ years is then
subtracted from the 20-year recharge to arrive at
the pumping limit for the next six months.
Calculated values, based on the estimated 1990
water year runoff, are given in Table 14
(Appendix B).

If the difference in recharge and pumping in a well
field area is within limits established below
(generally the maximum annual production capability
of the well field area), provisions will be made in
the pumping program that establish limits that are

designed to prevent mining during the October to
March period of the then-current runoff year, or
the subsequent runoff year in the event of a
below-average runoff year. It is expected that
these limits will be modified as production
capacity in each well field area changes.

APPROXIMATE ANNUAL MAXIMUM
WELLFIELD PUMPING CAPACITIES

WELL FIELD AREA	ACRE-FEET/YEAR
Laws	38000
Bishop	12000
Big Pine	42000
Taboose-Thibaut	55000
Ind-Sym-Bairs	41000
Lone Pine	2700

In summary, a section of the annual pumping pro-
gram, developed in April of each year, will include
an update on the final calculations of recharge and
pumping for the previous 20 water years, and will
include a section of the estimated recharge of the
then-current water year and pumping limits.

V. FURTHER STUDIES

The scientific effort for gathering data for managing the
Owens Valley watershed and its groundwater-dependent plants
has been unprecedented in scope. Investigation specifi-
cally aimed toward managing the Owens Valley hydro-ecology
has been performed from 1983 through present by the
U.S. Geological Survey, the USDA Soils Conservation
Service, City of Los Angeles Department of Water and Power,
and Inyo County Water Department. The results from this
work have been incorporated into the Agreement and the
Green Book. Even though much has been accomplished, the
scale of the Owens Valley, the complexity of the
hydro-ecological system, and the potential severity of the
consequences of an error in management require continuing
intensive effort to ensure that the goals and principles of
the Agreement are fully achieved. Therefore, studies
concerning monitoring techniques, plant distribution,
plant-water relationships, and the linkage between the
hydrologic system and groundwater-dependent plants should
continue.

This section lists the studies and projects that will be
conducted or are being considered by the Technical Group.
The pertinent sections in the Green Book are listed for
reference.

A. Projects

The projects described below do not require further
data gathering and are an adaptation of existing
techniques and computer software.

1. Analysis of Vegetation Map Data Base and
   Refinement, if necessary, of the Vegetation
   Management Maps (Green Book Section II)

The data base is currently undergoing further
analysis for several reasons:

a. To determine the ability to numerically dis-
   tinguish between vegetation communities.

b. To better determine Valley floor precipitation
   additional permanent stations for measuring
   precipitation will be established on the Valley
   floor. The locations of these stations will be
   determined in relationship to the presence of
   the two existing stations (Bishop and
   Independence) and the existing understanding of
   precipitation patterns.

2. Establish a Geographical Information System (GIS)
   for the Owens Valley

   A GIS would assist in managing the hydro-ecological
   system of the Owens Valley by providing multiple
   map overlays of information pertaining to the
   Valley's natural resources. The data for the GIS
   are described in Section III.A.

B. Studies

   1. Determine the statistical variability of all mea-
      surements and relationships presently used for
      monitoring. This will include:

      a. Point-frame measurement of leaf area (III.C)

      b. Psychrometer measurements (III.F)

      c. The Miller technique for estimating soil water
         content from soil water potential (III.F)

d. Maximum effective rooting depths for common
    Owens Valley-floor perennials (III.G)

e. Absolute limiting water potential for several
    perennial species (III.G)

f. Depthwise decrementing for plant-available
    water (III.G)

g. Seasonal variability of average leaf angle for
    common Owens Valley-floor perennials (III.C)

2. Analysis of the techniques for estimating leaf area
   and transpiration are ultimately used to project
   plant water requirements. These methods are cur-
   rently being analyzed using data from the coopera-
   tive studies and collected during monitoring. The
   results of this analysis may be used to revise the
   techniques described in Sections III.C and III.D to
   achieve the greatest accuracy of the estimates.

3. Develop data and relationships that are presently
   estimated for untested species. This would include:

a. Transpiration for several common perennial
    shrubs and forbs (III.C)

b. Average leaf angles for several common
    perennial species (III.C)

c. Absolute limiting water potentials for untested
    Owens Valley-floor perennials (III.G)

4. Investigate the statistical ability for determining
   vegetation change on the Owens Valley floor using

the existing transect record obtained during the
inventory of dominant vegetation.

5. Remote Sensing (III.B)

    a. Determine the patterns of climatic response and
        vegetation change using the existing satellite
        record beginning in 1974. This project should
        determine whether satellite imagery data is
        sufficient for tracking vegetation change.

    b. Test and develop airborne systems to monitor
        the Owens Valley vegetation. This study will
        be tied closely with the implementation of the
        GIS.

6. Revegetation

    Large-scale tests of revegetation and restoration
    should be attempted on Owens Valley floor lands.
    These tests should be made on a variety of soils in
    areas which have shown poor natural revegetation
    success. The goal of revegetation studies would be
    to establish perennial vegetation cover, though not
    necessarily to its previous composition.
    Restoration studies would attempt to restore an
    impacted area to its original vegetation cover and
    composition.

7. Rainfall Importance

    Determination of the importance of rainfall in
    replenishing soil moisture. The study sites would
    be located in conjunction with the permanent
    precipitation stations noted above. Soil moisture

measurements would follow established methodology (III.F).

8. Type D Vegetation Monitoring Techniques

Riparian and marshland vegetation falls within the Type D management category. A study will be initiated to refine the present methodology and investigate alternative methods to improve monitoring of riparian and marshland vegetation.

9. Plant Responses

The purpose of this study would be to gain an understanding of the demographics of Owens Valley plant species and how this vegetation responds to hydrologic management.

10. Erosion and Sediment Transport Along the Owens River

Changes in riparian vegetation, sediment movement, and to old river oxbows and meanders from fluctuating flows in a natural river, such as the Owens River, are not well understood.

In 1975, the U.S. Geological Survey, in cooperation with the Department of Fish and Game and LADWP, investigated the effects of long-term erosion and man's influence on river morphology of a segment of the Owens River below Pleasant Valley Reservoir.

Los Angeles and Inyo County will re-examine and expand these investigations on the changes in the Owens River.

absolute limiting soil water potential: The soil water potential below which a plant is incapable of extracting additional water and which is achieved in the bulk volume of soil only with the presence of sufficient root density (see also limiting soil water potential and depthwise limiting soil water potential).

aquifer - A geologic formation, group of formations, or part of a formation that is water bearing and which transmits water in sufficient quantity to supply springs and pumping wells.

aquifer system - Two or more interconnected aquifers (e.g., a confined aquifer underlying an unconfined aquifer).

aquifer test - A field in situ study aimed at obtaining controlled aquifer system response data whereby a production well is pumped at several fractions of full capacity and/or at a constant rate, and water levels are measured at frequent intervals in the production well and nearby observation wells.

available soil water - That water in the soil that a plant can absorb. Per the techniques that have been adopted, this is the amount of water throughout the rooting zone calculated to be greater than the depthwise limiting water content in each of four soil slices.

average leaf angle - Leaves forming a plant canopy have complex alignments with no easily recognizable patter. Even so, when statistical and trigonometric techniques are applied on many individuals of the same species, a shared average angle of alignment is obtained. This average angle may then be used as a calibrated value to correct point-frame measurements to calculate leaf area index (LAI).

calibration - Developing and applying a mathematical relationship to interpret a measured value. Measurement of a parameter often requires the use of mathematical relationships to calculate a parameter from a reading that is obtained. Each psychrometer used for measuring soil water potential requires such calibration, and this calibration procedure shall be known as **"psychrometer calibration."** Each monitored soil slice also requires calibration to apply the Miller curve technique, this shall be known as **"Miller Method calibration."**

characteristic curve - A function relating the soil water potential to the soil water content. The Miller Method has been chosen as the means for calculating characteristic

curves for interpreting the soil water at monitoring sites. Characteristic curves may use either weight or volumetric water content. The Miller Method utilizes weight water content to avoid systematic error of water content relative to soil water potential that may be induced by variable dry bulk density.

Day of Year - Abbreviated **DOY**, this refers to the calendar day of the year (from 1 to 365). Important plant responses, such as LAI and transpiration, can be modeled using DOY as the independent variable. A table is provided to permit calculating DOY from the calendar date.

TABLE FOR CALCULATING DOY FROM CALENDAR DATE

MONTH	JULIAN DAY
January	day of month + 0
February	day of month + 31
March	day of month + 59
April	day of month + 90
May	day of month + 120
June	day of month + 151
July	day of month + 182
August	day of month + 213
September	day of month + 244
October	day of month + 274
November	day of month + 305
December	day of month + 335

demographics - The study of populations and their distribution over time. Demographics is an important component of monitoring because the monitoring criteria were formulated to preserve the existing individual plants and does not address the cumulative effect of drought over time upon reproductive processes and recruitment.

depthwise limiting water potential - Due to problems of scale for measuring soil water potential and water content, the absolute limiting soil water potential for a plant is not achievable throughout the rooting zone. This occurs, in part, because root density decreases exponentially with depth. As the soil dries, the unsaturated hydraulic conductivity increases exponentially and water is essentially stranded in the soil volume that lies among rootlets. Thus, even though the water potential of the rhizosphere (zone immediately around each root) may approach the absolute limiting soil water potential, bulk measurements will show

water content considerably in excess of that limit. This phenomenon induces a gradual depthwise increase in the measured limit for soil water extraction by roots. This increase in limiting water potential has been determined empirically under field conditions and has been termed **"depthwise limiting water potential."**

dry bulk density - The soil dry bulk density, expressed as g/cm^3, is calculated by obtaining a volumetric soil sample from an undisturbed soil and dividing by its oven dry weight.

evapotranspiration - Abbreviated as **ET**, this term refers to water loss from natural areas as a combination of transpiration from plants and evaporation from the soil surface.

flowing well - A well penetrating a confined aquifer in which the water level rises above the ground surface.

hydrogeology - The study of groundwater, with particular emphasis given to its chemistry, mode of migration, and relation to the geologic environment.

hydrograph - A time series plot of water data.

hydrologic system - An assemblage of interrelated elements related to water flow, such as surface water systems, groundwater systems, and aqueduct systems.

intermountain slopes - Ungaged area between streams at the base of mountains.

leaf area index - Abbreviated as **LAI** and measured in units of m^2/m^2, this is a measure of leaf area per unit area of ground. Leaf area index is important because it is a driving function for transpiration and because it permits detailed numerical analysis of the vegetation growing on a site.

limiting soil water content - The soil water content corresponding to the limiting water potential. Limiting soil water contents are different for species with differing drought tolerances.

limiting soil water potential - The lower limit of osmotic adjustment which enables a plant to establish a gradient for flow into the root. This limiting water potential must be determined experimentally. Limiting water potentials will vary with species and--due to depthwise exponentially decreasing root density--with depth.

maximum effective depth of rooting - Abbreviated **MED**, is that depth where the functional density of roots approaches zero. This depth may be determined empirically by extracting cores under conditions when the water table is much

deeper than the root zone. A line predicting root density per depth is then calculated using linear regression technique. The MED is the point where the line intersects the y axis (depth), thus predicting root density equivalent to zero.

Miller Method - Named for Reuben F. Miller, the researcher who suggested the method, this simple technique evaluates a logarithmic transformation of soil water potential--pF--as a linear function of weight water content for pF values in excess of 2.3. The point 2.3 represents the water retained after unimpeded gravity drainage. According to the family of Miller curves, any curve may be calculated using a modification of the quadratic formula given only one point of pF versus weight water content.

model - Simplification of reality--either conceptual or mathematical.

monitoring well - A well constructed for the purpose of observing or monitoring groundwater conditions.

mulch - Any nonliving plant tissue encountered during sampling.

pF - "Pressure force" is analogous to pH (the base 10 logarithm of the hydrogen ion concentration, using the absolute value of the base 10 exponent). pF may be calculated by first converting the water potential in MPa to pressure head expressed as cm of water, taking the absolute value and then the base 10 logarithm. This may be expressed as $pF = \log_{10}(10230 * MPa)$. Note that MPa and cm of water head are both terms describing pressure, and that 1 MPa = 10 bars.

parcel (or vegetation parcel) - This is an area of land covered by vegetation of similar composition throughout and which is distinguishable from the surrounding vegetation cover.

phreatophyte - Used as a functional term to describe a plant that habitually receives a portion of its water supplied from the water table or overlying capillary fringe.

phreatophytic - Of, or pertaining to, a plant acquiring a portion of its water supply from groundwater.

piezometer - A test well for measuring the pressure head of groundwater. With a nonconfined system, the pressure head is equal to the free water table surface.

plant community - A recognizable association of plant species which grow together because of shared tolerances to climate and soil conditions.

point frame - A mobile structure used for sampling vegetation. Point frames generally consist of an upright frame with a cross piece through which pins are passed to sample the vegetation beneath. Pin contacts with leaves are judged only for pin points because the line of pin travel theoretically represents only one dimension. Since the sampling represents the pin-leaf contacts as a two-dimensional plane, calculation of LAI requires correction for the complex alignment of leaves.

recharge - Water that enters a groundwater basin--either from the surface or from the subsurface from adjacent basins.

recruitment - The process of replacement of aging and declining members of a plant community.

regression analysis - A statistical analysis of data that relates one variable (the dependent variable) to one or more independent variables.

remote sensing - Pertaining to acquiring or using data gathered by aircraft or satellite for studying processes on the Earth's surface. Examples of remote sensing data are air photos and satellite images.

retained water - Water that remains in a soil horizon following a drop of the water table and unimpeded drainage. Retained water is synonymous with field capacity and is roughly equivalent to a pF = 2.3.

root density - Is a measure of root length per unit volume of soil. Because root density does not follow a normal statistical distribution, before it can be treated using normal statistics, it must first be transformed by adding 1 and then taking the base 10 logarithm.

rhizosphere - The thin layer of soil lying immediately around all active roots of a plant which, due to processes involving hydrologic conductivity and dynamic diurnal fluctuations of root water potential, may have very different water potentials than the surrounding bulk soil.

runoff year - April-March

safe yield - The amount of water that can be withdrawn annually from a groundwater basin without producing an undesired result.

transect - A line which is located across vegetation to guide sampling. Since the placement of natural vegetation tends to be random, a linear feature, such as a transect, produces a random sample.

transpiration - The process of evaporative loss of water from plant leaves.

underflow - Lateral subsurface flow into and out of adjacent groundwater basins (e.g., Chalfant Valley and Round Valley).

volumetric water content - The soil water content expressed in terms of the volume of water per volume of soil and may be in the form of either a decimal fraction or percent. Volumetric water content is calculated from weight water content by multiplying by the dry bulk density for that soil volume.

water year - October-September

weight water content - The soil water content expressed in terms of weight water per weight of soil. Weight water content may be expressed as either a decimal fraction or percent, and is determined gravimetrically after oven drying.

well - Any artificial excavation constructed by any method for the purpose of extracting water from--or injecting water into--the underground.

well field - A group of wells.

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APPENDIX A

TRANSECT SHEET

BISHOP   Quadrangle

Lease: John Doe   Photo #: 21-11-81

Parcel #: 30/329

SPECIES	T-1	tot. hits	T-2	tot. hits	T-3	tot. hits	T-4	tot. hits	T-5	tot. hits	T-6	tot. hits	% COMPOSITION	
EPNE		6		11		8		8		10		4	47	60
TEAX		4						5		7		5	21	27
ATCO												2	2	3
TEGL						2						3	5	6
SAVE														T
PSPO														T
ORHY		2						1					3	4
STEPH														T
AAFF														T
% Total Cover		12		11		10		14		17		14	78	13

Community Description: EPNE-TEAX(13)

EPNE 60, TEAX 27, TEGL 6, ORHY 4, ATCO 2, SAVE T, PSPO T, STEPH T, AAFF T

Remarks:

LAND CLASSIFICATION

AND

NATURAL COMMUNITY DESCRIPTIONS

FOR THE

OWENS VALLEY[1]

*10000   Non-Native Vegetation & Misc. Lands

    11000   Irrigated Agriculture

    12000   Urban

    13000   Bodies of Water

        13100   Permanent Lakes & Reservoirs

        13200   Intermittent Ponds

    14000   Barren Lands - ABAG

30000   Scrub & Chaparral

    34000   Mojavean Desert Scrub

        34100   Mojave Creosote Bush Scrub

        34200   Mojave Mixed Scrub & Steppe

            34210   Mojave Mixed Woody Scrub

        34300   Blackbrush Scrub

    35000   Great Basin Scrub

        35100   Great Basin Mixed Scrub

        35200   Sagebrush Scrub

            35210   Big Sagebrush Scrub

        35400   Rabbitbrush Scrub

* Classification specific to the Owens Valley—not included in the Natural Community
classification developed by Cheatham and Haller (1975).

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[1] Based on Natural Community classification developed by Cheatham and Haller (1975) as
modified by Glen Holstein, Deborah Jensen, and Robert Holland [California Department of
Fish and Game, Natural Diversity Data Base (NDDB)].

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36000    Chenopod Scrub
         36100    Desert Chenopod Scrub
                  36110    Desert Saltbush Scrub
                  36120    Desert Sink Scrub
                  36130    Desert Greasewood Scrub
                  36140    Shadscale Scrub
                 *36150    Nevada Saltbush Scrub


40000    Grasslands, Meadows
         45000    Meadow & Seep
                  45300    Alkali Meadows & Seeps
                           45310    Alkali Meadow
                           45320    Alkali Seep
                          *45330    Rush/Sedge Meadow
                          *45340    Rabbitbrush Meadow
                          *45350    Nevada Saltbush Meadow
                 *45500    Non-Native Meadow
         46000    Alkali Playa


50000    Bog & Marsh
         52000    Marsh & Swamp
                  52300    Alkali Marsh
                           52320    Transmontane Alkali Marsh


60000    Riparian & Bottomland Habitat
         61000    Riparian Forests
                  61600    Modoc - Great Basin Riparian Forest
                           61610    Modoc - Great Basin Cottonwood/Willow Riparian Forest
                  61700    Mojave Riparian Forest
         63000    Riparian Scrub
                  63500    Montane Riparian Scrub
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* Classification specific to the Owens Valley--not included in the Natural Community
  classification developed by Cheatham and Haller (1975).

63600   Modoc – Great Basin Riparian Scrub

63800   Colorado Riparian Scrub

      63810   Tamarisk Scrub

70000   Woodland

  *76000   Non-Native Woodland

    *76100   Black Locust Woodland

* Classification specific to the Owens Valley--not included in the Natural Community classification developed by Cheatham and Haller (1975).

ELEMENT NAME: Mojave Creosote Bush Scrub   ELEMENT CODE: 34100

DESCRIPTION: Shrubs, 0.5-3 m tall, widely spaced, usually with bare ground between. Growth occurs during spring (or rarely in summer or fall) if rainfall is sufficient. Growth is prevented by cold in winter and limited by drought at other seasons. Many species of ephemeral herbs may flower in late March and April if the winter rains are sufficient. Other, less numerous species of annuals appear following summer thundershowers. This is the basic creosote scrub of the Mojave Desert, dominated by Larrea tridentata and Ambrosia dumosa.

SITE FACTORS: Well-drained secondary soils with very low available water holding capacity on slopes, fans, and valleys rather than upland sites with thin residual soils or sites with high soil salinity. Winter temperatures often below freezing. Intergrades at higher elevations with Shadscale Scrub (36140), or Joshua Tree Woodland (73000); at lower elevations or more osmotic sites with Desert Chenopod Scrub (36100).

CHARACTERISTIC SPECIES: Ambrosia dumosa, Cassia armata, Ephedra nevadensis, Hymenoclea salsola, Larrea tridentata, Lycium spp.

DISTRIBUTION: Extensive from the Death Valley region southward across the Mojave Desert to the little San Bernardino Mountains, eastward to northwestern Arizona and southern Nevada. The dominant plant community below 3,000 or 4,000 feet (910 or 1,210 m) in this region.

SOURCES: 1, 8, 13, 48, 63, 91, 127, 128, 130

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ELEMENT NAME: Mojave Mixed Woody Scrub   ELEMENT CODE: 34210

DESCRIPTION: A complex scrub, open enough to be passable, and usually characterized by Yucca brevifolia herbertii, Eriogonum fasciculatum polifolium, and Isomeris arborea arborea. Most of the constituent species also occur in other nearby communities.

SITE FACTORS: Very shallow, overly-drained, often rolling to steep soils, usually derived from granitic parent materials. These sites have extremely low water holding capacity, mild alkalinity, and are not very saline. Intergrades on deeper soils (with higher water holding capacity) or at cooler elevations with Great Basin Scrub (35000), Blackbrush Scrub (34300), or Piñyon Woodlands (72000); at warmer elevations with Creosote Bush Scrub (33100, 34100).

CHARACTERISTIC SPECIES: Ambrosia dumosa, Atriplex spp., Brickellia oblongifolia linifolia, Camissonia kernensis, Chrysothamnus teretifolius, Coleogyne ramosissima, Dalea fremontii, Ephedra nevadensis, E. viridis, Ericameria cooperi, E. linearifolia, Eriogonum fasciculatum polifolium, Eucnide urens, Galium argense, Gilia cana elongata, Grayia spinosa, Hymenoclea salsola, Isomeris arborea arborea, Lupinus excubitus, Mentzelia involucrata, Opuntia basilaris,

Phacelia nashiana, Purshia glandulosa, Salazaria mexicana, Salvia dorrii, Tetradymia axillaris, Yucca brevifolia herbertii

DISTRIBUTION: Widely but erratically scattered along the eastern base of the Sierra Nevada from the southwestern Owens Valley southward along the Tehachapis, San Gabriel, San Bernardino, San Jacinto, and Peninsular ranges to northern Baja California. Typically occurs between 2,000-5,000 feet.

SOURCES: 1, 13, 48, 62, 91

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ELEMENT NAME: Blackbush Scrub   ELEMENT CODE: 34300

DESCRIPTION: Low, often intricately branched shrubs, 0.5-1 m tall, with crowns usually not touching and with bare ground between plants. Dominated by Coleogyne ramosissima. Most growth and flowering occurs in late spring. Dormant in winter (from cold) and probably in summer and fall (from drought).

SITE FACTORS: On dry, well-drained slopes and flats with shallow often calcareous soils of very low water holding capacity, often intergrading with Great Basin Sagebrush Scrub (35210), Joshua Tree Woodland (73000), or Pinyon/Juniper Woodlands (72000), but typically at somewhat lower elevations, warmer, and drier.

CHARACTERISTIC SPECIES: Agave utahensis, Artemisia spinescens, Atriplex confertifolia, Chrysothamnus teretifolius, Coleogyne ramosissima, Ephedra nevadensis, Ericameria cooperi, Eriogonum fasciculatum polifolium, Ceratoides lanata, Hilaria rigida, Grayia spinosa, Menodora spinescens, Salazaria mexicana, Salvia dorrii, Sitanion hystrix, Spheralcea ambigua, Stipa speciosa, Thamnosma montana, Yucca baccata

DISTRIBUTION: From the Owens Valley region (Inyo and southern Mono counties) to the Mojave Desert (Kern and San Bernardino counties). Typically between 4,000 and 7,000 feet.

SOURCES: 1, 48, 63, 91, 292

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ELEMENT NAME: Great Basin Mixed Scrub   ELEMENT CODE: 35100

DESCRIPTION: A low, shrubby, open community with several species contributing to canopy. Total cover is low (approximately 20%) and dominants usually include Ephedra nevadensis, Psorothamnus arborescens var. minutifolius, Atriplex confertifolia and Tetradymia axillaris.

SITE FACTORS: Usually coarse to moderately coarse textured soils with a low available water holding capacity, on slopes and alluvial fans. Intergrades at higher elevations with Blackbush Scrub (34300) or Sagebrush Scrub (35200); at lower elevations with Desert Chenopod Scrub (36100).

CHARACTERISTIC SPECIES: Artemisia spinescens, A. tridentata ssp. tridentata, Atriplex canescens, A. confertifolia, A. polycarpa, Ceratoides lanata, Ephedra

nevadensis, Eriogonum inflatum, Grayia spinosa, Ozyzopsis hymenoides, Psorothamnus arborescens var. minutifolius, Psorothamnus polyadenia, Purshia glandulosa, Stipa speciosa, Tetradymia axillaris

DISTRIBUTION: Distributed in the northern Mojave and the Great Basin deserts.

SOURCES: 292

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ELEMENT NAME: Big Sagebrush Scrub   ELEMENT CODE: 35210

DESCRIPTION: Mostly soft-woody shrubs, 0.5-2 m tall, usually with bare ground underneath and between shrubs. Artemisia tridentata is dominant. Growth occurs mostly in late spring and early summer. Some species flower in late spring (Coleogyne, Purshia), others in early fall (Artemisia, Chrysothamnus). Dormant in winter. Young et al (65) recognize 15 communities within this unit.

SITE FACTORS: Occurs on a wide variety of soils and terrain, from rocky, well-drained slopes to fine-textured valley soils with high water table. May be colder (from cold air drainage), drier, or with less well-drained more alkaline soil than Piñyon/Juniper Woodland (72000), a frequent associate.

CHARACTERISTIC SPECIES: Agropyron spicatum, Artemisia tridentata, Atriplex canescens, Bromus marginatus, Chrysothamnus nauseosus, Coleogyne ramosissima, Elymus cinereus, Ephedra nevadensis Festuca idahoensis, Hilaria jamesii, Oryzopsis hymenoides, Purshia glandulosa, Purshia tridentata, Sporobolus airoides, Stipa comata, S. lettermanii, S. occidentalis, S. thurberiana, S. speciosa

DISTRIBUTION: Widely distributed east of the Cascade/Sierra Nevada crest, especially in Modoc, Lassen, Mono and Inyo counties. Scattered localities within and along the margins of the Mojave and Sonoran deserts (on desert mountain ranges) and in interior cismontane southern California. Usually occurs between 4,000 and 9,000 feet (1,210 and 2,730 m). Distributed extensively through the Intermountain West.

SOURCES: 1, 48, 65, 68, 132

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ELEMENT NAME: Rabbitbrush Scrub   ELEMENT CODE: 35400

DESCRIPTION: In the Owens Valley, this community is dominated by Chrysothamnus nauseosus. Usually .5-1 m tall, with fairly evenly spaced gray shrubs flowering in late summer or fall. At higher elevations, this community is dominated by Chrysothamnus viscidiflorus.

SITE FACTORS: In the Owens Valley, this community is found predominantly on abandoned farmlands. Soils are coarse to moderately coarse-textured and range from well-drained to excessively drained. Available water capacity is low to moderate.

CHARACTERISTIC SPECIES: Artemisia tridentata ssp. tridentata, Atriplex canescens, Atriplex torreyi, Bassia hyssopifolia, Chrysothamnus nauseosus, Salsola kali var. tenuifolia, annual forbs

DISTRIBUTION: Great Basin and western margin of the Mojave Desert, reaching west across the Sierra/Cascade Axis into the drainages of Kern, Feather, and Pit Rivers.

SOURCES: 1, 65

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ELEMENT NAME: Desert Saltbush Scrub   ELEMENT CODE: 36110

DESCRIPTION: Usually low, grayish, microphyllous shrubs, 0.3-1 m tall, with some succulent species. Total cover often low, with much bare ground between the widely spaced shrubs. Stands typically are strongly dominated by a single Atriplex species.

SITE FACTORS: In the Owens Valley, found on coarse to moderately coarse-textured soils. They are very deep and range from well-drained to excessively drained. Available water capacity ranges from very low to moderate. Usually found where the alluvial fans and Valley floor join.

CHARACTERISTIC SPECIES: Ambrosia dumosa, Atriplex argentea, Atriplex canescens, A. confertifolia, A. elegans ssp. fasciculata, A. hymenolytra, A. lentiformis, A. nuttallii, A. phyllostegia, A. polycarpa, A. pusilla, A. torreyi, Hymenoclea salsola, Kochia californica, Lycium andersonii, L. cooperi, Prosopis glandulosa var. torreyana, Suaeda occidentalis

DISTRIBUTION: Widely scattered in the Colorado, Mojave, and Great Basin deserts.

SOURCES: 1, 8, 48, 130, 132, 133

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ELEMENT NAME: Desert Sink Scrub   ELEMENT CODE: 36120

DESCRIPTION: In the Owens Valley, this is a shrub/grassland community with sparse cover. Sarcobatus vermiculatus and an Atriplex sp. comprise at least 20 percent of the cover, and Sporobolus airoides and Distichlis spicata var. stricta are the dominant grass species.

SITE FACTORS: Wind-blown hummocks and alkali slicks are common. Soils are moderately coarse-textured and range from shallow to very deep. They range from somewhat poorly drained to well-drained. Available water capacity ranges from very low to very high. These soils are sodic and often have a high water table with a salt crust at the surface. May intergrade with Alkaline Meadow (45310).

CHARACTERISTIC SPECIES: Allenrolfea occidentalis, Aster intricatus, Atriplex confertifolia, Atriplex parryi, Cleome sparsiflora, Cressa truxillensis minima, Distichlis spicata var. stricta, Erysimum capitatum bealianum, Heliotropium curassavicum oculatum, Kochia californica, Monolepis nuttalliana, Nitrophila

occidentalis, Oxystylis lutea, Sarcobatus vermiculatus, Sesuvium verrucosum, Sporobolus airoides, Suaeda torreyana, Wislizenia refracta

DISTRIBUTION: Moist valley bottoms and lake beds scattered throughout the Sonoran Desert, Mojave Desert, Owens Valley, and nearby areas, usually about 4,000 feet.

SOURCES: 1, 8, 13, 48, 65, 294

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ELEMENT NAME: Desert Greasewood Scrub   ELEMENT CODE: 36130

DESCRIPTION: Low shrubs up to 1 m tall with some succulent species. Total cover often low (approximately 15%). Stands are typically dominated by Sarcobatus vermiculatus and Atriplex confertifolia.

SITE FACTORS: Often on valley bottoms, and playa margins, with moderately coarse textured soils. Available water capacity is low to moderate for most soils. Wind erosion is severe, creating small dunes around the shrubs. The water table is in excess of 10 feet. Intergrades with Desert Sink Scrub (36120), near the valley bottom, and Shadscale Scrub (36140) at the toe of the alluvial fans.

CHARACTERISTIC SPECIES: Atriplex canescens, Atriplex confertifolia, Atriplex parryi, Atriplex polycarpa, Atriplex torreyi, Ephedra nevadensis, Oryzopsis hymenoides, Psorothamnus polyadenia, Sarcobatus vermiculatus, Suaeda torreyana, Tetradymia glabrata

DISTRIBUTION: Widely scattered through the Great Basin, Mojave and Colorado deserts.

SOURCES: 1, 6, 292, 293, 295

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ELEMENT NAME: Shadscale Scrub   ELEMENT CODE: 36140

DESCRIPTION: Low, intricately branched, often spiny shrubs, 0.3-0.6 m tall, usually well-spaced with bare ground between dominant Atriplex confertifolia and Artemisia spinescens. Growth, flowering, and dormancy sequence similar to Blackbush Scrub (34300), but usually a little earlier because of slightly higher temperatures and/or greater aridity.

SITE FACTORS: Often on poorly-drained flats with heavy, somewhat alkaline soil, adjacent to Desert Chenopod Scrub (36100). Also on well-drained slopes at higher elevations, intergrading at its upper limits with Blackbush Scrub (34300), Great Basin Sagebrush Scrub (35200) or Joshua Tree Woodland (73000). May occur above Creosote Bush Scrub (34100) on well-drained slopes or below it in poorly-drained basins with cold air accumulation.

CHARACTERISTIC SPECIES: Abronia villosa, Ambrosia dumosa, Artemisia spinescens, Atriplex confertifolia, Atriplex hymenolytra, Atriplex polycarpa, Coleogyne ramosissima, Ephedra nevadensis, Ceratoides lanata, Grayia spinosa,

<u>Gutierrezia</u> spp., <u>Haplopappus</u> <u>acradenius</u>, <u>Kochia</u> <u>americana</u>, <u>Menodora</u> <u>spinescens</u>, <u>Oryzopsis</u> <u>hymenoides</u>, <u>Sarcobatus</u> <u>vermiculatus</u>, <u>Tetradymia</u> <u>axillaris</u>, <u>Tetradymia</u> <u>glabrata</u>

DISTRIBUTION: From the Owens Valley region (Inyo County) to the Mojave Desert (Kern and San Bernardino counties), and north and eastward across southern Nevada. Typically between 3,000 and 6,000 feet (910 and 1,800 m).

SOURCES: 1, 13, 48, 63, 64, 136, 293

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ELEMENT NAME: Nevada Saltbush Scrub   ELEMENT CODE: 36150

DESCRIPTION: A moderately tall shrubland with average total cover around 20-30%. <u>Atriplex</u> <u>torreyi</u> is dominant. Growth mostly occurs in late spring and early summer, flowering mid-summer. Perennial grass cover is sparse, as compared to Nevada Saltbush Meadow (45350), which has a dense understory of perennial grasses.

SITE FACTORS: Found on moderately coarse to moderately fine-textured alkaline soils with available water holding capacity ranging from moderate to high. Often with high water table and a salty soil surface crust. This appears to be a disturbed community, formerly an Alkaline Meadow (45310) or Desert Sink Scrub (36120) which <u>Atriplex</u> <u>torreyi</u> has invaded and now dominates.

CHARACTERISTIC SPECIES: <u>Artemisia</u> <u>tridentata</u> var. <u>tridentata</u>, <u>Atriplex</u> <u>confertifolia</u>, <u>Atriplex</u> <u>torreyi</u>, <u>Chrysothamnus</u> <u>nauseosus</u>, <u>Distichlis</u> <u>spicata</u> var. <u>stricta</u>, <u>Glycyrrhiza</u> <u>lepidota</u>, <u>Juncus</u> <u>balticus</u>, <u>Sarcobatus</u> <u>vermiculatus</u>, <u>Sporobolus</u> <u>airoides</u>, <u>Suaeda</u> <u>torreyana</u>

DISTRIBUTION: The valley bottom of the Owens Valley. Also occurs in the Mojave Desert, Nevada, and Utah.

SOURCES: 295

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ELEMENT NAME: Alkali Meadow   ELEMENT CODE: 45310

DESCRIPTION: Dense to fairly open growth of perennial grasses and sedges. Usually low growing, but occasionally with tufts to 1 m high (<u>Sporobolus</u> <u>airoides</u>). Growing and flowering season from late spring to early fall. Dominants are: <u>Sporobolus</u> <u>airoides</u>, <u>Distichlis</u> <u>spicata</u> var. <u>stricta</u>, <u>Juncus</u> <u>balticus</u>.

SITE FACTORS: On medium to moderately fine-textured, more or less permanently moist, alkaline soils. May intergrade with Great Basin Sagebrush (35200), Shadscale Scrub (34400, 35400), or Great Basin Grassland (43100) on moist, nonalkaline soil; with Desert Sink Scrub (36120) on drier, more alkaline soils; with Non-Native Grassland (42200), and Northern Claypan Vernal Pools (44120) on drier, less alkaline soils of the Central Valley; or with Alkali Marsh (52300) on permanently flooded sites.

CHARACTERISTIC SPECIES: Allenrolfea occidentalis, Anemopsis californica, Atriplex torreyi, Carex spp., Chrysothamnus nauseosus, Cordylanthus mollis hispidus, Distichlis spicata var. stricta, Leymus triticoides, Juncus spp., Muhlenbergia asperifolia, Poa juncifolia, Phragmites australis, Sarcobatus vermiculatus, Sida hederacea, Sisyrinchium halophyllum, Spartina gracilis, Sporobolus airoides, Triglochin concinna debilis

DISTRIBUTION: In valley bottoms and on the lower portions of alluvial slopes east of the Cascades and Sierra Nevada, from the Modoc Plateau to Owens Valley at elevations of 3,500 to 7,000 feet (1,070 to 2,130 m). Also occurring around Alkali Seeps (45320) arising from the Valley Springs Formation of eastern Central Valley from Kern to Placer counties, on salt-affected grasslands of the San Joaquin Valley trough and the Livermore Valley, and the salty grasslands of the western Sacramento Valley from San Joaquin to Glenn and Colusa counties.

SOURCES: 1, 48, 130, 133

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ELEMENT NAME: Alkali Seep   ELEMENT CODE: 45320

DESCRIPTION: A relatively complete cover with grasses, herbs and shrubs, growing throughout the year in areas with mild winters. Relatively few species.

SITE FACTORS: Permanently moist or wet alkaline seeps. Often associated with Alkali Meadows (45400).

CHARACTERISTIC SPECIES: Carex spp., Distichlis spicata var. stricta, Juncus balticus, Nitrophila occidentalis, Phragmites australis, Rosa woodsii, Salix spp., Sporobolus airoides

DISTRIBUTION: Scattered throughout the desert regions of California; less common in other areas.

SOURCES: 48, 133

- - - - - - - - - -

ELEMENT NAME: Rush/Sedge Meadow   ELEMENT CODE: 45330

DESCRIPTION: Dense growth of many perennial grasses, sedges and forbs. Some grasses are introduced species due to pasture improvement by broadcasting seed. Growing and flowering season from late spring to early fall.

SITE FACTORS: On medium to moderately fine-textured, more or less permanently moist alkaline soils. Supplemental irrigation may occur on some sites during the growing season. May intergrade with Alkali Meadow (45310) or Non-Native Meadow (45500).

CHARACTERISTIC SPECIES: Carex spp., Cynodon dactylon, Distichlis spicata var. stricta, Eleocharis spp., Festuca arundinacea, Glycyrrhiza lepidota, Haplopappus racemosus, Helianthus annuus, Hordeum jubatum, Juncus balticus, Leymus

triticoides, <u>Lotus</u> <u>corniculatus</u>, <u>Melilotus</u> <u>alba</u>, <u>Muhlenbergia</u> <u>asperifolia</u>, <u>Paspalum</u> <u>distichum</u>, <u>Sporobolus</u> <u>airoides</u>, <u>Trifolium</u> spp.

DISTRIBUTION: Scattered throughout the Owens Valley.

SOURCES: None

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ELEMENT NAME: Rabbitbrush Meadow   ELEMENT CODE: 45340

DESCRIPTION: A moderate stand of perennial grasses with <u>Chrysothamnus</u> <u>nauseosus</u> dominant. Total cover is around 50%. Growing and flowering season from late spring to early fall.

SITE FACTORS: A disturbed (fire, grazing) Alkali Meadow (45310) which has been invaded by <u>Chrysothamnus</u> <u>nauseosus</u>. On medium to moderately fine-textured, more or less permanently moist alkaline soils.

CHARACTERISTIC SPECIES: <u>Atriplex</u> <u>torreyi</u>, <u>Chrysothamnus</u> <u>nauseosus</u>, <u>Distichlis</u> <u>spicata</u> var. <u>stricta</u>, <u>Glycyrrhiza</u> <u>lepidota</u>, <u>Juncus</u> <u>balticus</u>, <u>Leymus</u> <u>triticoides</u>, <u>Sida</u> <u>hederacea</u>, <u>Sporobolus</u> <u>airoides</u>

DISTRIBUTION: Scattered throughout the Owens Valley.

SOURCES: None

- - - - - - - - - -

ELEMENT NAME: Nevada Saltbush Meadow   ELEMENT CODE: 45350

DESCRIPTION: A moderate stand of perennial grasses with <u>Atriplex</u> <u>torreyi</u> dominant. Total cover is around 40%. Growing and flowering season from late spring to early fall.

SITE FACTORS: A disturbed (fire, grazing) Alkali Meadow (45310) which has been invaded by <u>Atriplex</u> <u>torreyi</u>. On moderately coarse to moderately fine-textured, more or less permanently moist alkaline soils.

CHARACTERISTIC SPECIES: <u>Allenrolfea</u> <u>occidentalis</u>, <u>Atriplex</u> <u>torreyi</u>, <u>Bassia</u> <u>hyssopifolia</u>, <u>Chrysothamnus</u> <u>nauseosus</u>, <u>Distichlis</u> <u>spicata</u> var. <u>stricta</u>, <u>Glycyrrhiza</u> <u>lepidota</u>, <u>Juncus</u> <u>balticus</u>, <u>Leymus</u> <u>cinereus</u>, <u>Sarcobatus</u> <u>vermiculatus</u>, <u>Sida</u> <u>hederacea</u>, <u>Sporobolus</u> <u>airoides</u>, <u>Suaeda</u> <u>torreyana</u>

DISTRIBUTION: Scattered throughout the Owens Valley.

SOURCES: None

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ELEMENT NAME: Non-Native Meadow   ELEMENT CODE: 45500

DESCRIPTION: A dense stand of introduced perennial grasses. Total cover is
around 90%. Some native grasses, sedges and forbs may be present. Growing and
flowering season from late spring to early fall.

SITE FACTORS: On medium to moderately fine-textured, more or less permanently
moist soils. Non-native species introduced by broadcasting a commercial pasture
mix. Supplemental irrigation may occur during the growing season. May inter-
grade with Alkali Meadow (45310) or Rush/Sedge Meadow (45330).

CHARACTERISTIC SPECIES: Agropyron intermedium, Carex spp., Cynodon dactylon,
Distichlis spicata var. stricta, Eleocharis spp., Festuca arundinacea, Hordeum
jubatum, Juncus balticus, Leymus triticoides, Lotus corniculatus, Paspalum
distichum, Polypogon monspeliensis, Trifolium spp.

DISTRIBUTION: Scattered throughout the Owens Valley.

SOURCES: None

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ELEMENT NAME: Alkali Playa   ELEMENT CODE: 46000

DESCRIPTION: Usually low, grayish, microphyllous and succulent shrubs to ap-
proximately 1 m tall. Total cover usually low due to wide spacing between shrubs
and minimally developed understory.

SITE FACTORS: Poorly drained soils with high salinity and/or alkalinity due to
evaporation of water that accumulates in closed drainages. Often with high water
table and with salt crust on the surface.

CHARACTERISTIC SPECIES: Allenrolfea occidentalis, Atriplex confertifolia,
A. parryi, Distichlis spicata var. stricta, Sarcobatus vermiculatus

DISTRIBUTION: Closed basins of the Transmontane Deserts, and some smaller
examples in the Central Valley.

SOURCES: 1, 133, 185

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ELEMENT NAME: Transmontane Alkali Marsh   ELEMENT CODE: 52320

DESCRIPTION: Very similar to Cismontane Alkali Marsh (52310) with many of the
same species. Differs in having a shorter growing season confined more strictly
to the summer and with winter dormancy more absolute.

SITE FACTORS: Very similar to Valley Alkali Marsh (52310) but subject to much
lower temperatures in winter, often well below freezing. Intergrades with
Transmontane Freshwater Marshes (52420) in less alkaline situations; with Vernal
Marshes (52500) where summer drying occurs; with Chenopod Scrubs (36000) in areas
of moist, highly alkaline soil that usually lack surface water; and with Alkali
Meadows (45400) where the soil is moist and moderately alkaline.

CHARACTERISTIC SPECIES: Anemopsis californica, Carex spp., Distichlis spicata var. stricta, Juncus balticus, Juncus cooperi, Nitrophila occidentalis, Phragmites australis, Scirpus acutus, Scirpus nevadensis, Scirpus olneyi, S. robustus spp., Triglochin concinna var. debilis, Typha domingensis, T. latifolia

DISTRIBUTION: Lake beds, margins of springs, and river bottomlands of the Modoc Plateau in eastern Siskiyou County, Modoc County, and Lassen County, east of the Sierra Nevada in Mono County, and Inyo County, especially near Bridgeport and in Owens Valley, and sporadically around wet spots in the Mojave. Elevations 3,000 to 7,000 feet.

SOURCES: 1, 48, 130, 133

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ELEMENT NAME: Modoc/Great Basin Cottonwood/Willow   ELEMENT CODE: 61610
                Riparian Forest

DESCRIPTION: An open-canopied, broadleafed, winter-deciduous riparian forest dominated by Populus fremontii and Salix laevigata without much shrubby under-story other than scattered Chrysothamnus nauseosus consimilis. Leymus triticoides, Phragmites australis, and several other graminoids form a fairly dense (though usually grazed) herb layer.

SITE FACTORS: Along the larger streams at lower montane elevations, usually where streams debauch onto valleys and begin to grade.

CHARACTERISTIC SPECIES: Chrysothamnus nauseosus consimilis, Distichlis spicata var. stricta, Leymus triticoides, Juncus balticus montanus, Phragmites australis, Populus fremontii, Rosa woodsii ultramontana, Salix exiqua, S. laevigata, Scirpus acutus, Sporobolus airoides, Typha latifolia

DISTRIBUTION: Along lower elevation streams of the eastern Sierra Nevada (usu-ally below about 7,000 feet), from Inyo County north to the Modoc Plateau and southern Oregon.

SOURCES: 208, 281

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ELEMENT NAME: Mojave Riparian Forest   ELEMENT CODE: 61700

DESCRIPTION: A relatively open, broadleafed, winter-deciduous streamside forest dominated by Populus fremontii, Salix gooddingii, and S. laevigata. The open canopy allows a dense shrubby understory of Atriplex torreyi, Chrysothamnus nauseosus, Rosa woodsii, and Salix exiqua to prosper. Similar to and inter-grading in the lower elevations of Inyo County with Modoc/Great Basin Cottonwood/Willow Riparian Forest (61610).

SITE FACTORS: Flat, fine-grained, subirrigated alluvium along perennial desert rivers.

CHARACTERISTIC SPECIES: Atriplex confertifolia, A. parryi, A. torreyi, Chrysothamnus nauseosus, Distichlis spicata var. stricta, [Eleagnus

angustifolia], Forestiera neomexicana, Phragmites australis, Populus fremontii
(and var. macdougallii), Rosa woodsii, Salix exigua, S. gooddingii, S. laevigata,
Sarcobatus vermiculatus, Scirpus acutus, Sporobolus airoides, [Tamarix
ramosissima], Typha latifolia

DISTRIBUTION: Along the larger desert rivers (Owens, Mojave, Colorado) where the
vegetation has not been cleared for irrigated agriculture. Generally below about
4,000 feet.

SOURCES: 208, 219, 280

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ELEMENT NAME: Montane Riparian Scrub   ELEMENT CODE: 63500

DESCRIPTION: Open to dense, broadleafed, winter-deciduous shrubby riparian
thickets usually dominated by any of several Salix species, Alnus, or Cornus.
This catch-all community includes a bewildering array of cover types that require
substantial study.

SITE FACTORS: Relatively fine-textured alluvium along fairly low-gradient
reaches of snowmelt-fed streams. Often occurs as a thin scrubby corridor through
Montane (45100) or Subalpine and Alpine Meadows (45200).

CHARACTERISTIC SPECIES: Alnus tenuifolia, Cornus sessilis, C. stolonifera,
Lonicera involucrata, Salix anglorum antiplasti, S. caudata, S. drummondiana
subcoerulea, S. eastwoodiae, S. geyeriana argentea, S. jepsonii, S. lemmonii,
S. ligulifolia, S. lutea, S. lutea watsonii, S. mackenziana, S. melanopsis,
S. orestera, S. planifolia monica, S. pseudocordata, S. scouleriana, Spiraea
densiflora

DISTRIBUTION: Widely scattered above 5,000-7,000 feet, throughout montane parts
of the Klamath, Sierra Nevada, and southern California mountains. Most of these
have been ravaged by past livestock grazing and today are threatened by dewater-
ing from small hydro projects.

SOURCES: 208

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ELEMENT NAME: Modoc/Great Basin Riparian Scrub   ELEMENT CODE: 63600

DESCRIPTION: Open to impenetrably dense, broadleafed, winter-deciduous thickets
dominated by shrubby willows. Open stands frequently have dense herbaceous
understories of Juncus spp., Carex spp., or Distichlis spicata var. stricta.

SITE FACTORS: Relatively fine-grained sand and gravel bars and low, wet alluvial
terraces along perennial and intermittent streams. Also along margins of
springs.

CHARACTERISTIC SPECIES: Artemisia tridentata, Betula occidentalis, Carex spp.,
Chrysothamnus nauseosus, Distichlis spicata var. stricta, Juncus spp., Rosa
woodsii, Salix commutata, S. exigua, S. lutea, S. lutea watsonii, S. melanopsis,
Shepherdia argentea

- 145 -

DISTRIBUTION: Along most of the streams and creeks of the Modoc Plateau and Great Basin deserts, from far northeastern California south to Mono and Inyo counties.

SOURCES: 208, 280

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ELEMENT NAME: Tamarisk Scrub   ELEMENT CODE: 63810

DESCRIPTION: A weedy, virtual monoculture of any of several Tamarix species, usually supplanting native vegetation following major disturbance.

SITE FACTORS: Sandy or gravelly braided washes or intermittent streams, often in areas where high evaporation increases the stream's saltiness. Tamarisk is a strong phreatophyte and a prolific seeder, attributes which predispose the species to be aggressive competitors in disturbed riparian corridors, and water-spreading areas.

CHARACTERISTIC SPECIES: Atriplex confertifolia, Atriplex lentiformis, Atriplex torreyi, Coldenia palmeri, Distichlis spicata var. stricta, Pleuchea sericea, Salix exigua, Scirpus acutus, Sporobolus airoides, [Tamarix chinensis, T. ramosissima], Typha latifolia

DISTRIBUTION: Widely scattered and increasing its range, throughout the drier parts of California from the rainshadow east of the Inner North Coast Ranges south through the Great Valley to southern California and across the deserts to Nevada, Arizona and beyond.

SOURCES: 83, 216, 289

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ELEMENT NAME: Black Locust Woodland   ELEMENT CODE: 76100

DESCRIPTION: A fairly open woodland dominated by Robinia pseudoacacia. Understory usually consists of shrubs and perennial grasses.

SITE FACTORS: Robinia pseudoacacia was extensively planted as an ornamental and windbreak tree. It has become more or less naturalized, often spreading by means of underground stems and forming thickets of trees.

CHARACTERISTIC SPECIES: Chrysothamnus nauseosus, Distichlis spicata var. stricta, Robinia pseudoacacia, Rosa woodsii, Salix spp., Salsola kali var. tenuifolia, Sporobolus airoides

DISTRIBUTION: Scattered throughout the Owens Valley.

SOURCES: None

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Natural Diversity Data Base
California Department of Fish and Game

N.D.D.B. Natural Community
Descriptions, November 1986 copies
available at:

> Department of Water and Power
> City of Los Angeles
> 873 N. Main Street, Suite 227
> Bishop, California 93514

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* EVAPOTRANSPIRATION *

PARCEL	%LIVE COVER	TOTAL ACRES	LIVE ACRES	COVER TYPE	% COMP	ABSOLUTE ACRES	TRANSPIRATION FT	TRANSPIRATION AC-FT	EVAPORATION FT	EVAPORATION AC-FT	EVAPOTRANSPIRATION AC-FT	FEET	INCHES
76	75	134	100.50	LETR	39	39.20	1.11	43.51	45330	RUSH/SEDGE MEADOW			
				DISPS2	24	24.12	.87	20.98					
				CAPR5	6	6.03	1.11	6.69					
				JUBA	6	6.03	1.11	6.69					
				GLLE3	4	4.02	1.11	4.46					
				AAFF	4	4.02	1.11	4.46					
				SALIX	2	2.01	4.00	8.04					
				ROWO	2	2.01	1.11	2.23					
				EQUIS	2	2.01	1.11	2.23					
				IRMI	1	1.01	1.11	1.12					
NAT MDW1		PARCEL TOTALS			90	90.46	1.11	100.41	.45	60.30	160.71	1.20	14.40
77	90	17	15.30	POFR3	43	6.58	4.00	26.32	61610	MODOC-G.B. COTTW/WILLOW RIPARIAN			
	FINE TEXTURED SOIL			SALIX	42	6.43	4.00	25.72					
				LETR	4	.61	4.00	2.44					
				CAPR5	4	.61	4.00	2.44					
OTHER		PARCEL TOTALS			93	14.23	4.00	56.92	.30	5.10	62.02	3.65	43.80
78	51	28	14.28	DISPS2	57	8.14	1.69	13.76	45310	ALKALI MEADOW			
	FINE TEXTURED SOIL			GLLE3	19	2.71	1.80	4.88					
				LETR	8	1.14	1.80	2.05					
				CHNA2	5	.71	3.08	2.19					
				CAPR5	2	.29	1.80	.52					
NAT MDW1		PARCEL TOTALS			91	12.99	1.80	23.40	.59	16.63	40.03	1.43	17.16
79	100	58	58.00	URBAN	100	58.00	2.00	116.00	12000	URBAN			
URBAN		PARCEL TOTALS			100	58.00	2.00	116.00	.30	17.40	133.40	2.30	27.60
80	42	29	12.18	DISPS2	60	7.31	.87	6.36	45310	ALKALI MEADOW			
				LETR	15	1.83	.87	1.59					
				CAPR5	12	1.46	.87	1.27					
				GLLE3	6	.73	.87	.64					
NAT MDW2		PARCEL TOTALS			93	11.33	.87	9.86	.30	8.70	18.56	.64	7.68
81	100	3	3.00	IRAG	100	-	-	-	11000	IRRIGATED AGRICULTURE			
IRAG		PARCEL TOTALS			100	3.00	2.92	8.76	.30	.90	9.66	3.22	38.64
82	42	73	30.66	DISPS2	60	18.40	.87	16.01	45310	ALKALI MEADOW			
				LETR	15	4.60	.87	4.00					
				CAPR5	12	3.68	.87	3.20					
				GLLE3	6	1.84	.87	1.60					
NAT MDW2		PARCEL TOTALS			93	28.52	.87	24.81	.30	21.90	46.71	.64	7.68

APPENDIX B

Table 1 – Parameters Used In Stream Recharge Calculations

STREAM	BOM (CFS)	SRR	SRA	SRB	SL (FT)	SW (FT)	SET (FT\YR)	VC
Fish Slough	8.54	0.03	0.00	0.00	8600	50	3.92	0.30
Silver Creek	1.59	0.70	0.00	0.00	22100	50	3.92	0.30
Coldwater Creek	1.02	0.44	0.00	0.00	8200	50	3.92	0.30
Poleta Canyon	0.01	1.00	0.00	0.00	0	50	3.92	0.30
Horton Creek	10.19	0.10	0.00	0.00	12400	50	3.92	0.30
McGee Creek	2.47	0.63	0.00	0.00	14100	50	3.92	0.30
Birch Creek (Near Bishop)	1.64	1.00	0.00	0.00	9800	50	3.92	0.30
Bishop Creek	93.57	0.20	0.00	0.00	22900	50	3.92	0.30
Rawson Creek	1.86	0.44	0.10	0.00	8800	50	3.92	0.30
Freeman Creek	1.15	0.94	0.00	0.00	13100	50	3.92	0.30
Shannon Creek	1.53	0.70	0.00	0.00	12900	50	3.92	0.30
Black Canyon	0.01	1.00	0.00	0.00	0	50	3.92	0.30
Baker Creek	8.58	0.21	0.00	0.00	13200	50	3.92	0.30
Big Pine Creek	41.77	0.10	0.00	0.10	24000	50	3.92	0.30
Birch Creek (Near Big Pine)	7.68	0.25	0.30	0.15	37900	50	3.92	0.30
Tinemaha, Red, Fuller Creek	13.42	0.55	0.30	0.05	77500	50	3.92	0.30
Westgard Pass	0.01	1.00	0.00	0.00	0	50	3.92	0.30
Waucoba Canyon	0.01	1.00	0.00	0.00	0	50	3.92	0.30
Taboose Creek	9.23	0.57	0.34	0.00	40800	50	3.92	0.30
Goodale Creek	7.17	0.70	0.08	0.00	45300	50	3.92	0.30
Division Creek	8.54	1.25	0.00	0.00	14700	50	3.92	0.30
Sawmill Creek	5.30	0.54	0.00	0.00	9400	50	3.92	0.30
Thibaut Creek	2.36	0.78	0.00	0.00	13400	50	3.92	0.30
Oak Creek (Includes North Fork)	16.56	0.76	0.20	0.00	56100	50	3.92	0.30
Independence Creek	14.00	0.61	0.10	0.02	31000	50	3.92	0.30
Symmes Creek	3.87	0.99	0.10	0.02	44100	50	3.92	0.30
Shepherd Creek	10.86	0.47	0.06	0.15	41900	50	3.92	0.30
Bairs Creek (Includes North Fork)	5.19	0.84	0.03	0.00	53600	50	3.92	0.30
Georges Creek	8.90	0.59	0.02	0.00	36900	50	3.92	0.30
Hogback Creek	4.11	0.72	0.01	0.00	45100	50	3.92	0.30
Mazourka Canyon	0.30	1.00	0.00	0.00	0	50	3.92	0.30
Lone Pine Creek	13.01	0.35	0.02	0.00	41600	50	3.92	0.30
Tuttle Creek	9.36	0.25	0.00	0.06	32000	50	3.92	0.30
Diaz Creek	2.50	0.90	0.00	0.00	30100	50	3.92	0.30
Lubkin Creek (Includes North Fork)	3.05	0.81	0.00	0.00	30000	50	3.92	0.30

Source: Wes Danskin of the United States Geological Survey

Note: BOM averaged using Water Years 1935 through 1984

Where:

    BOM = Average flow at base of mountain station
    SRR = Ratio of stream loss to BOM
    SRA = Fractional increase in stream length above station
    SRB = Fractional increase in stream length below station
    SL = Length of stream
    SW = Width of stream
    SET = Annual evaporation from the area near stream channel
    VC = Fraction of area near stream channel covered by vegetation

Table 2 - Runoff Factors For Water Years 1969 Through 1989

WATER YEAR	RO
1969	1.96
1970	0.99
1971	0.79
1972	0.69
1973	1.06
1974	1.07
1975	0.88
1976	0.64
1977	0.55
1978	1.34
1979	0.98
1980	1.42
1981	0.89
1982	1.43
1983	1.89
1984	1.32
1985	0.98
1986	1.58
1987	0.78
1988	0.68
1989	0.64

Source: Los Angeles Aqueduct System Totals And Means
         Hydro Years - Owens Valley Runoff

Note: RO = Yearly Runoff / Longterm Average Runoff (469,852 Acre-Feet
       Based On Water Years 1935 Through 1984)

Table 3 – Calculated Stream Recharge In Acre-Feet For Water Years 1969 Through 1989

STREAM	WATER YEAR										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Fish Slough	352	172	135	116	185	187	152	107	90	237	170
Silver Creek	1549	768	607	526	824	832	679	486	413	1050	760
Coldwater Creek	626	311	246	213	333	337	275	197	168	424	307
Poleta Canyon	14	7	6	5	8	8	6	5	4	10	7
Horton Creek	1429	714	566	492	765	773	632	455	389	972	706
McGee Creek	2189	1096	871	758	1175	1186	972	702	601	1491	1085
Birch Creek (Near Bishop)	2314	1162	925	806	1245	1257	1032	747	640	1578	1150
Bishop Creek	26524	13382	10672	9317	14330	14466	11892	8640	7421	18124	13246
Rawson Creek	1266	633	503	438	679	685	562	405	347	861	627
Freeman Creek	1516	757	601	522	812	820	671	483	413	1031	749
Shannon Creek	1502	750	595	518	804	812	665	479	409	1022	742
Black Canyon	14	7	6	5	8	8	6	5	4	10	7
Baker Creek	2539	1274	1013	882	1365	1378	1130	817	700	1730	1261
Big Pine Creek	6487	3261	2595	2263	3494	3527	2895	2097	1797	4425	3227
Birch Creek (Near Big Pine)	3899	1944	1541	1340	2085	2105	1723	1239	1057	2650	1924
Tinemaha, Red, Fuller Creek	14035	7037	5594	4873	7542	7614	6244	4512	3863	9562	6965
Westgard Pass	14	7	6	5	8	8	6	5	4	10	7
Waucoba Canyon	14	7	6	5	8	8	6	5	4	10	7
Taboose Creek	9949	4998	3977	3467	5355	5406	4436	3211	2752	6784	4947
Goodale Creek	7630	3824	3039	2647	4099	4138	3392	2450	2097	5197	3785
Division Creek	15128	7631	6086	5313	8172	8249	6781	4926	4231	10336	7554
Sawmill Creek	4048	2039	1624	1417	2184	2204	1811	1313	1127	2764	2018
Thibaut Creek	2594	1301	1035	901	1395	1408	1155	835	715	1768	1288
Oak Creek (Includes North Fork)	21355	10749	8562	7469	11514	11624	9546	6922	5938	14576	10639
Independence Creek	13530	6814	5429	4736	7298	7367	6052	4390	3767	9237	6744
Symmes Creek	6029	3016	2395	2084	3233	3265	2674	1929	1649	4103	2985
Shepherd Creek	8707	4370	3476	3029	4683	4728	3878	2805	2403	5935	4325
Bairs Creek (Includes North Fork)	6299	3146	2496	2171	3374	3406	2788	2008	1716	4284	3114
Georges Creek	7550	3789	3013	2626	4060	4099	3362	2432	2083	5146	3750
Hogback Creek	4180	2081	1649	1432	2233	2254	1843	1324	1129	2839	2060
Mazourka Canyon	426	215	172	150	230	232	191	139	119	291	213
Lone Pine Creek	6534	3273	2600	2264	3508	3542	2903	2096	1793	4450	3239
Tuttle Creek	3476	1735	1375	1196	1860	1878	1537	1106	944	2363	1717
Diaz Creek	3152	1572	1246	1083	1686	1702	1393	1002	855	2142	1556
Lubkin Creek (Includes North Fork)	3465	1730	1372	1194	1855	1873	1533	1104	943	2356	1712
VALLEY TOTAL	190335	95572	76034	66263	102409	103386	84823	61378	52585	129768	94593

Table 3 – Calculated Stream Recharge In Acre-Feet For Water Years 1969 Through 1989

STREAM	WATER YEAR									
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Fish Slough	252	153	254	339	233	170	281	133	115	107
Silver Creek	1114	687	1122	1493	1034	760	1243	599	518	486
Coldwater Creek	450	278	454	603	418	307	502	242	210	197
Poleta Canyon	10	6	10	14	10	7	11	6	5	5
Horton Creek	1031	640	1038	1378	957	706	1149	559	485	455
McGee Creek	1581	984	1592	2110	1468	1085	1761	860	747	702
Birch Creek (Near Bishop)	1673	1043	1685	2231	1554	1150	1863	913	794	747
Bishop Creek	19208	12027	19343	25575	17853	13246	21375	10537	9182	8640
Rawson Creek	914	568	920	1220	848	627	1018	496	431	405
Freeman Creek	1094	679	1101	1461	1015	749	1219	593	514	483
Shannon Creek	1084	673	1091	1448	1006	742	1208	587	510	479
Black Canyon	10	6	10	14	10	7	11	6	5	5
Baker Creek	1834	1143	1848	2448	1704	1261	2043	1000	869	817
Big Pine Creek	4691	2928	4724	6255	4358	3227	5223	2562	2230	2097
Birch Creek (Near Big Pine)	2811	1743	2831	3758	2609	1924	3133	1521	1319	1239
Tinemaha, Red, Fuller Creek	10139	6316	10211	13530	9418	6965	11293	5522	4801	4512
Westgard Pass	10	6	10	14	10	7	11	6	5	5
Waucoba Canyon	10	6	10	14	10	7	11	6	5	5
Taboose Creek	7192	4487	7243	9591	6682	4947	8009	3926	3416	3211
Goodale Creek	5511	3431	5551	7356	5119	3785	6139	3000	2607	2450
Division Creek	10954	6858	11032	14587	10182	7554	12191	6008	5235	4926
Sawmill Creek	2930	1831	2950	3903	2722	2018	3261	1603	1396	1313
Thibaut Creek	1874	1168	1888	2501	1741	1288	2088	1021	888	835
Oak Creek (Includes North Fork)	15450	9655	15560	20589	14357	10639	17200	8453	7359	6922
Independence Creek	9791	6121	9860	13046	9099	6744	10899	5359	4667	4390
Symmes Creek	4352	2705	4383	5812	4041	2985	4849	2364	2053	1929
Shepherd Creek	6293	3923	6337	8394	5846	4325	7008	3431	2984	2805
Bairs Creek (Includes North Fork)	4544	2821	4576	6072	4219	3114	5064	2463	2138	2008
Georges Creek	5456	3401	5495	7279	5069	3750	6077	2975	2587	2432
Hogback Creek	3012	1865	3033	4029	2795	2060	3358	1627	1410	1324
Mazourka Canyon	308	193	311	410	287	213	343	169	148	139
Lone Pine Creek	4719	2936	4752	6299	4382	3239	5257	2567	2230	2096
Tuttle Creek	2507	1555	2525	3351	2327	1717	2794	1357	1178	1106
Diaz Creek	2272	1409	2289	3038	2110	1556	2533	1230	1067	1002
Lubkin Creek (Includes North Fork)	2499	1551	2517	3340	2320	1712	2785	1355	1176	1104
VALLEY TOTAL	137580	85796	138556	183502	127813	94593	153210	75056	65284	61378

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Table 4 – Parameters Used In Ungaged Intermountain Slope Recharge Calculations

UNGAGED INTERMOUNTAIN SLOPE	UR (CFS)	UNGAGED INTERMOUNTAIN SLOPE	UR (CFS)
Chalfant - Fish Slough	0.032	Goodale - Division	1.237
Fish Slough - Owens River	0.028	Division - Sawmill	0.494
Chalfant - Coldwater	0.100	Sawmill - Thibaut	0.755
Coldwater - Silver	0.280	Thibaut - North Oak	0.308
Silver - Poleta	0.240	North Oak - South Oak	1.536
Owens River - Horton	0.008	Papoose Flat - Black Jack Mine	0.032
Horton - McGee	0.140	Black Jack Mine - Mazourka Canyon	0.064
McGee - Birch (Near Bishop)	0.020	South Oak - Independence	0.502
Birch (Near Bishop) - Bishop	0.120	Independence - Symmes	2.675
Bishop - Rawson	2.850	Symmes - Shepherd	0.223
Rawson - Freeman	1.350	Shepherd - North Bairs	0.478
Freeman - Shannon	0.750	North Bairs - Bairs	0.220
Poleta - Black Canyon	0.026	Bairs - Georges	0.640
Shannon - Baker	3.150	Georges - Hogback	1.106
Baker - Big Pine	0.600	Hogback - Lone Pine	1.143
Big Pine - Crater Mountain (Front)	1.125	Mazourka Canyon - Reward	0.036
Crater Mountain (Front) - Birch	0.900	Reward - Owenyo	0.026
Birch (Near Big Pine) - Fuller	1.350	Owenyo - Long John Canyon	0.032
Fuller - Tinemaha	0.450	Alabama Hills (NW Side)	0.058
Tinemaha - Red Mountain	1.290	Alabama Hills (NE Side)	0.028
Black Canyon - Westgard Pass	0.036	Lone Pine - Tuttle	1.200
Westgard Pass - Waucoba Canyon	0.022	Tuttle - Diaz	0.900
Waucoba Canyon - Harkless Flats	0.058	Diaz - North Lubkin	0.300
Harkless Flats - Papoose Flat	0.030	Lubkin - Model Boundary	0.750
Poverty Hills	0.040	Long John Canyon - End Of Model	0.028
Red Mountain - Taboose	1.496	Alabama Hills (SW Side)	0.032
Taboose - Goodale	2.434	Alabama Hills (SE Side)	0.026

Source: Wes Danskin of the United States Geological Survey

Where:
    UR = Longterm average ungaged recharge

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Table 5 – Calculated Ungaged Intermountain Slope Recharge In Acre–Feet For Water Years 1969 Through 1989

UNGAGED INTERMOUNTAIN SLOPE	WATER YEAR							
	1969	1970	1971	1972	1973	1974	1975	1976
Chalfant - Fish Slough	45	23	18	16	25	25	20	15
Fish Slough - Owens River	40	20	16	14	21	22	18	13
Chalfant - Coldwater	142	72	57	50	77	77	64	46
Coldwater - Silver	397	201	160	140	215	217	178	130
Silver - Poleta	341	172	137	120	184	186	153	111
Owens River - Horton	11	6	5	4	6	6	5	4
Horton - McGee	199	100	80	70	107	108	89	65
McGee - Birch (Near Bishop)	28	14	11	10	15	15	13	9
Birch (Near Bishop) - Bishop	170	86	69	60	92	93	76	56
Bishop - Rawson	4044	2043	1630	1424	2187	2208	1816	1321
Rawson - Freeman	1916	968	772	674	1036	1046	860	626
Freeman - Shannon	1064	538	429	375	576	581	478	348
Poleta - Black Canyon	37	19	15	13	20	20	17	12
Shannon - Baker	4470	2258	1802	1574	2417	2440	2007	1460
Baker - Big Pine	851	430	343	300	460	465	382	278
Big Pine - Crater Mountain (Front)	1596	806	643	562	863	871	717	521
Crater Mountain (Front) - Birch	1277	645	515	450	691	697	573	417
Birch (Near Big Pine) - Fuller	1916	968	772	674	1036	1046	860	626
Fuller - Tinemaha	639	323	257	225	345	349	287	209
Tinemaha - Red Mountain	1830	925	738	644	990	999	822	598
Black Canyon - Westgard Pass	51	26	21	18	28	28	23	17
Westgard Pass - Waucoba Canyon	31	16	13	11	17	17	14	10
Waucoba Canyon - Harkless Flats	82	42	33	29	45	45	37	27
Harkless Flats - Papoose Flat	43	22	17	15	23	23	19	14
Poverty Hills	57	29	23	20	31	31	25	19
Red Mountain - Taboose	2123	1072	856	747	1148	1159	953	693
Taboose - Goodale	3454	1745	1392	1216	1868	1885	1551	1128
Goodale - Division	1755	887	707	618	949	958	788	573
Division - Sawmill	701	354	283	247	379	383	315	229
Sawmill - Thibaut	1071	541	432	377	579	585	481	350
Thibaut - North Oak	437	221	176	154	236	239	196	143
North Oak - South Oak	2180	1101	878	767	1179	1190	979	712
Papoose Flat - Black Jack Mine	45	23	18	16	25	25	20	15
Black Jack Mine - Mazourka Canyon	91	46	37	32	49	50	41	30
South Oak - Independence	712	360	287	251	385	389	320	233
Independence - Symmes	3796	1917	1530	1336	2053	2072	1704	1239
Symmes - Shepherd	316	160	128	111	171	173	142	103
Shepherd - North Bairs	678	343	273	239	367	370	305	221
North Bairs - Bairs	312	158	126	110	169	170	140	102
Bairs - Georges	908	459	366	320	— 491	496	408	.297
Georges - Hogback	1569	793	633	552	849	857	705	512
Hogback - Lone Pine	1622	819	654	571	877	885	728	530
Mazourka Canyon - Reward	51	26	21	18	28	28	23	17
Reward - Owenyo	37	19	15	13	20	20	17	12
Owenyo - Long John Canyon	45	23	18	16	25	25	20	15
Alabama Hills (NW Side)	82	42	33	29	45	45	37	27
Alabama Hills (NE Side)	40	20	16	14	21	22	18	13
Lone Pine - Tuttle	1703	860	686	599	921	930	765	556
Tuttle - Diaz	1277	645	515	450	691	697	573	417
Diaz - North Lubkin	426	215	172	150	230	232	191	139
Lubkin - Model Boundary	1064	538	429	375	576	581	478	348
Long John Canyon - End Of Model	40	20	16	14	21	22	18	13
Alabama Hills (SW Side)	45	23	18	16	25	25	20	15
Alabama Hills (SE Side)	37	19	15	13	20	20	17	12
VALLEY TOTAL	47894	24201	19306	16863	25904	26148	21506	15646

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Table 5 - Calculated Ungaged Intermountain Slope Recharge In Acre-Feet For Water Years 1969 Through 1989

UNGAGED INTERMOUNTAIN SLOPE	WATER YEAR							
	1977	1978	1979	1980	1981	1982	1983	1984
Chalfant - Fish Slough	13	31	23	33	21	33	44	31
Fish Slough - Owens River	11	27	20	29	18	29	38	27
Chalfant - Coldwater	40	97	71	103	64	104	137	96
Coldwater - Silver	111	272	199	288	180	290	383	268
Silver - Poleta	96	233	170	247	155	248	328	229
Owens River - Horton	3	8	6	8	5	8	11	8
Horton - McGee	56	136	99	144	90	145	192	134
McGee - Birch (Near Bishop)	8	19	14	21	13	21	27	19
Birch (Near Bishop) - Bishop	48	116	85	123	77	124	164	115
Bishop - Rawson	1135	2765	2022	2930	1836	2951	3900	2724
Rawson - Freeman	538	1310	958	1388	870	1398	1847	1290
Freeman - Shannon	299	728	532	771	483	776	1026	717
Poleta - Black Canyon	10	25	18	27	17	27	36	25
Shannon - Baker	1254	3056	2235	3238	2030	3261	4310	3010
Baker - Big Pine	239	582	426	617	387	621	821	573
Big Pine - Crater Mountain (Front)	448	1091	798	1157	725	1165	1539	1075
Crater Mountain (Front) - Birch	358	873	639	925	580	932	1231	860
Birch (Near Big Pine) - Fuller	538	1310	958	1388	870	1398	1847	1290
Fuller - Tinemaha	179	437	319	463	290	466	616	430
Tinemaha - Red Mountain	514	1251	915	1326	831	1336	1765	1233
Black Canyon - Westgard Pass	14	35	26	37	23	37	49	34
Westgard Pass - Waucoba Canyon	9	21	16	23	14	23	30	21
Waucoba Canyon - Harkless Flats	23	56	41	60	37	60	79	55
Harkless Flats - Papoose Flat	12	29	21	31	19	31	41	29
Poverty Hills	16	39	28	41	26	41	55	38
Red Mountain - Taboose	596	1451	1061	1538	964	1549	2047	1430
Taboose - Goodale	969	2361	1727	2502	1568	2520	3330	2326
Goodale - Division	493	1200	878	1272	797	1281	1693	1182
Division - Sawmill	197	479	350	508	318	511	676	472
Sawmill - Thibaut	301	732	536	776	486	782	1033	722
Thibaut - North Oak	123	299	219	317	198	319	421	294
North Oak - South Oak	612	1490	1090	1579	990	1590	2102	1468
Papoose Flat - Black Jack Mine	13	31	23	33	21	33	44	31
Black Jack Mine - Mazourka Canyon	25	62	45	66	41	66	88	61
South Oak - Independence	200	487	356	516	323	520	687	480
Independence - Symmes	1065	2595	1898	2750	1724	2769	3660	2556
Symmes - Shepherd	89	216	158	229	144	231	305	213
Shepherd - North Bairs	190	464	339	491	308	495	654	457
North Bairs - Bairs	88	213	156	226	142	228	301	210
Bairs - Georges	255	621	454	658	412	663	876	612
Georges - Hogback	440	1073	785	1137	713	1145	1513	1057
Hogback - Lone Pine	455	1109	811	1175	736	1183	1564	1092
Mazourka Canyon - Reward	14	35	26	37	23	37	49	34
Reward - Owenyo	10	25	18	27	17	27	36	25
Owenyo - Long John Canyon	13	31	23	33	21	33	44	31
Alabama Hills (NW Side)	23	56	41	60	37	60	79	55
Alabama Hills (NE Side)	11	27	20	29	18	29	38	27
Lone Pine - Tuttle	478	1164	851	1234	773	1242	1642	1147
Tuttle - Diaz	358	873	639	925	580	932	1231	860
Diaz - North Lubkin	119	291	213	308	193	311	410	287
Lubkin - Model Boundary	299	728	532	771	483	776	1026	717
Long John Canyon - End Of Model	11	27	20	29	18	29	38	27
Alabama Hills (SW Side)	13	31	23	33	21	33	44	31
Alabama Hills (SE Side)	10	25	18	27	17	27	36	25
VALLEY TOTAL	13442	32743	23949	34704	21747	34946	46183	32260

Table 5 – Calculated Ungaged Intermountain Slope Recharge In Acre–Feet For Water Years 1969 Through 1989

UNGAGED INTERMOUNTAIN SLOPE	WATER YEAR				
	1985	1986	1987	1988	1989
Chalfant - Fish Slough	23	37	18	16	15
Fish Slough - Owens River	20	32	16	14	13
Chalfant - Coldwater	71	114	56	49	46
Coldwater - Silver	199	320	158	138	130
Silver - Poleta	170	275	136	118	111
Owens River - Horton	6	9	5	4	4
Horton - McGee	99	160	79	69	65
McGee - Birch (Near Bishop)	14	23	11	10	9
Birch (Near Bishop) - Bishop	85	137	68	59	56
Bishop - Rawson	2022	3260	1609	1403	1321
Rawson - Freeman	958	1544	762	665	626
Freeman - Shannon	532	858	424	369	348
Poleta - Black Canyon	18	30	15	13	12
Shannon - Baker	2235	3603	1779	1551	1460
Baker - Big Pine	426	686	339	295	278
Big Pine - Crater Mountain (Front)	798	1287	635	554	521
Crater Mountain (Front) - Birch	639	1029	508	443	417
Birch (Near Big Pine) - Fuller	958	1544	762	665	626
Fuller - Tinemaha	319	515	254	222	209
Tinemaha - Red Mountain	915	1476	728	635	598
Black Canyon - Westgard Pass	26	41	20	18	17
Westgard Pass - Waucoba Canyon	16	25	12	11	10
Waucoba Canyon - Harkless Flats	41	66	33	29	27
Harkless Flats - Papoose Flat	21	34	17	15	14
Poverty Hills	28	46	23	20	19
Red Mountain - Taboose	1061	1711	845	736	693
Taboose - Goodale	1727	2784	1374	1198	1128
Goodale - Division	878	1415	699	609	573
Division - Sawmill	350	565	279	243	229
Sawmill - Thibaut	536	864	426	372	350
Thibaut - North Oak	219	352	174	152	143
North Oak - South Oak	1090	1757	867	756	712
Papoose Flat - Black Jack Mine	23	37	18	16	15
Black Jack Mine - Mazourka Canyon	45	73	36	32	30
South Oak - Independence	356	574	283	247	233
Independence - Symmes	1898	3060	1511	1317	1239
Symmes - Shepherd	158	255	126	110	103
Shepherd - North Bairs	339	547	270	235	221
North Bairs - Bairs	156	252	124	108	102
Bairs - Georges	454	732	361	315	297
Georges - Hogback	785	1265	625	544	512
Hogback - Lone Pine	811	1307	645	563	530
Mazourka Canyon - Reward	26	41	20	18	17
Reward - Owenyo	18	30	15	13	12
Owenyo - Long John Canyon	23	37	18	16	15
Alabama Hills (NW Side)	41	66	33	29	27
Alabama Hills (NE Side)	20	32	16	14	13
Lone Pine - Tuttle	851	1373	678	591	556
Tuttle - Diaz	639	1029	508	443	417
Diaz - North Lubkin	213	343	169	148	139
Lubkin - Model Boundary	532	858	424	369	348
Long John Canyon - End Of Model	20	32	16	14	13
Alabama Hills (SW Side)	23	37	18	16	15
Alabama Hills (SE Side)	18	30	15	13	12
VALLEY TOTAL	23949	38609	19060	16622	15646

Table 6 - Canal Recharge Calculations - Spillgates

SPILLGATES	(*) SGR	1969-1970		1971-1986		1987		1988		1989	
		(a) SGD (CFS)	ANNUAL RECHARGE (AC-FT)	(b) SGD (CFS)	ANNUAL RECHARGE (AC-FT)	(c) SGD (CFS)	ANNUAL RECHARGE (AC-FT)	(c) SGD (CFS)	ANNUAL RECHARGE (AC-FT)	(c) SGD (CFS)	ANNUAL RECHARGE (AC-FT)
Owens River Intake	0.10	6.323	458	7.533	545	0.000	0	0.000	0	0.000	0
Blackrock	0.25	12.937	2341	8.498	1538	20.656	3739	18.142	3284	9.510	1721
Thibaut	0.25	3.306	598	2.566	464	1.852	335	1.463	265	1.620	293
Independence	0.25	1.392	252	2.871	520	2.166	392	1.743	315	3.064	555
Dean	0.30	1.584	344	1.592	346	0.990	215	0.735	160	0.764	166
Russell	0.30	1.460	317	1.966	427	0.845	184	0.675	147	0.725	157
Locust	0.30	2.665	579	2.699	586	1.035	225	2.582	561	4.503	978
Georges	0.25	0.253	46	0.620	112	0.200	36	0.598	108	0.655	119
Diaz	0.80	1.528	885	1.174	680	0.225	130	0.278	161	0.413	239
Lone Pine	0.80	0.824	477	2.729	1581	3.228	1870	3.142	1820	2.956	1712

Source: (*) Wes Danskin of the United States Geological Survey

Note: (a) SGD averaged using Water Years 1945 through 1970
      (b) SGD averaged using Water Years 1971 through 1986
      (c) SGD is actual spillgate discharge in each of Water Years 1987 through 1989

Where:
    SGR = Average annual recharge rate in spillgate area
    SGD = Discharge at spillgate

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Table 7 – Canal Recharge Calculations – Canals

CANALS	CR (CFS)	J (WATER YEARS)	ANNUAL RECHARGE (AC-FT)
McNally Upper And Laws Ditch	4.025	1969-1989	2914
McNally Lower To Geiger Canal	3.330	1969-1989	2411
A-Drain	1.995	1969-1989	1444
A-1 Drain	1.145	1969-1989	829
Bishop Creek Canal	1.130	1969-1989	818
Bishop Creek, North Fork	2.035	1969-1989	1473
Bishop Creek, South Fork	1.110	1969-1989	804
Bishop Creek Ditch	1.030	1969-1989	746
C-Drain	1.010	1969-1989	731
Collins Canal	2.530	1969, 1983	1832
Farmers Ditch To Duck Ponds	1.380	1969, 1978, 1980-1989	999
Ford Rawson Ditch	0.350	1969-1989	253
Geiger Canal	2.121	When RO > 1.25	1536
Hall Ditch	1.170	1969-1989	847
Indian Ditch	0.469	1969-1989	340
Indian (South) - Newlan Ditch	0.812	1969-1989	588
Owens River Canal (North)	1.590	1969	1151
Owens River Canal (South)	2.506	1969	1814
Rawson Canal Above Duck Ponds	1.370	1969-1989	992
Rawson Canal Below Duck Ponds	1.855	1969	1343
Big Pine Canal Above Baker Creek	1.230	1969-1989	890
Big Pine Canal Below Baker Creek	2.410	1969-1989	1745

Source: Wes Danskin of the United States Geological Survey

Note: Annual verification of each canal's operation is required

Where:
    CR = Average estimated canal recharge
    RO = Yearly Runoff / Longterm Average Runoff (See Table 2)

Table 8 – Parameters Used In Groundwater Recharge Calculations

RECHARGE AREA	(*) RR	(**) AL	(**) LADWP
McNally, South Of Upper #1	0.20	0.40	Laws - Operations
McNally, South Of Lower #1	0.20	0.40	Laws - Operations
Laws Ditch #1	0.20	0.20	Laws - Operations
McNally, South Of Upper #2	0.75	0.20	Laws - Groundwater Recharge
McNally, South Of Lower #2	0.75	0.60	Laws - Groundwater Recharge
Laws Ditch #2	0.75	0.20	Laws - Groundwater Recharge
Wood Lot	0.20	1.00	Laws - Recreation
Poleta Pasture Land	0.20	0.18	Laws - Enhancement/Mitigation
McNally Ponds	0.20	0.64	Laws - Enhancement/Mitigation
Lower McNally Extension	0.20	0.18	Laws - Enhancement/Mitigation
Farmer's Ponds #1	0.20	0.30	Bishop - Operations
Kingsley Ponds	0.20	0.10	Bishop - Operations
Arkansas Flats	0.20	0.20	Bishop - Operations
Partridge Slough	0.20	0.20	Bishop - Operations
Runkle Slough	0.20	0.20	Bishop - Operations
Buckley Ponds	0.70	(a)	Bishop - Recreation
Farmer's Ponds #2	0.70	(b)	Bishop - Recreation
Bishop Indian Reservation	0.30	(c)	Bishop - Indian Lands
East Of Crater Crater Mountain	0.20	1.00	Big Pine - Operations
Crater Mountain Edge 1	0.95	0.20	Big Pine - Groundwater Recharge
Crater Mountain Edge 2	0.95	0.10	Big Pine - Groundwater Recharge
Fish Springs	0.95	0.26	Big Pine - Groundwater Recharge
Klondike Lake	0.30	1.00	Big Pine - Enhancement/Mitigation
Big Pine Indian Reservation	0.50	(c)	Big Pine - Indian Lands
Blackrock/Thibaut Area 1	0.10	0.50	Overheads And Spillgates - Op + E\M + Gr Re + Rec
Blackrock/Thibaut Area 2	0.10	0.40	Overheads And Spillgates - Op + E\M + Gr Re + Rec
Blackrock/Thibaut Area 3	0.10	0.10	Overheads And Spillgates - Op + E\M + Gr Re + Rec
Independence Springfield	0.30	0.44	Tinemaha To Haiwee - Enhancement/Mitigation
Independence Indian Reservation	0.30	(c)	Tinemaha To Haiwee - Indian Lands
Lone Pine Richards	0.30	0.18	Tinemaha To Haiwee - Enhancement/Mitigation
Lone Pine Van Norman	0.30	0.18	Tinemaha To Haiwee - Enhancement/Mitigation
Lone Pine Indian Reservation	0.30	(c)	Overheads And Spillgates - Indian Lands

Source: (*) Wes Danskin of the United States Geological Survey
(**) Russ Rawson of the Los Angeles Department of Water and Power

Note: (a) AL = 1.00 for Years 1969 through 1982; AL = 0.67 thereafter
(b) AL = 0.00 for Years 1969 through 1982; AL = 0.33 thereafter
(c) No AL Value Required for Indian Lands

Where:
RR = Recharge rate
AL = Fraction of water allocated compared to total allocation
LADWP = Historical Uses And Losses (See Table 9)

Table 9 - Historical Water Uses In The Owens Valley Study Area

Laws Area

WATER YEAR	IRRIGATION (AC-FT)	STOCKWATER (AC-FT)	OPERATIONS (AC-FT)	ENHCMT/MITIG (AC-FT)	GRNDWTR RECHG (AC-FT)	RECREATION (AC-FT)	INDIAN LANDS (AC-FT)	TOTAL (AC-FT)
1971	3290	1082	0	0	0	0	0	4372
1972	3852	984	0	0	0	0	0	4836
1973	3900	1466	0	0	0	0	0	5366
1974	2995	1885	0	0	9656	0	0	14536
1975	3824	876	0	0	3963	0	0	8663
1976	2296	532	0	0	0	0	0	2828
1977	3945	420	0	0	0	0	0	4365
1978	4655	533	237	0	15674	0	0	21099
1979	3904	546	0	0	2690	0	0	7140
1980	5183	518	8	0	17935	0	0	23644
1981	4008	495	154	0	2595	0	0	7252
1982	3536	548	1	0	16198	22	0	20305
1983	4048	752	1937	0	30756	119	0	37612
1984	4216	522	1110	0	238	431	0	6517
1985	4386	507	1101	0	0	206	0	6200
1986	4738	521	5385	0	24497	132	0	35273
1987	6245	521	7703	2719	0	160	0	17348
1988	5580	535	5656	6182	0	314	0	18267
1989	5441	519	5209	8257	0	148	0	19574

Source: Russ Rawson of the Los Angeles Department of Water and Power

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Table 9 – Historical Water Uses In The Owens Valley Study Area

Bishop Area

WATER YEAR	IRRIGATION (AC-FT)	STOCKWATER (AC-FT)	OPERATIONS (AC-FT)	ENHCMT/MITIG (AC-FT)	GRNDWTR RECHG (AC-FT)	RECREATION (AC-FT)	INDIAN LANDS (AC-FT)	TOTAL (AC-FT)
1971	16798	3460	400	0	0	3094	2894	26646
1972	16427	3265	875	0	0	2937	3236	26740
1973	15826	4165	46	0	0	3146	3693	26876
1974	17622	3671	45	0	0	4473	3517	29328
1975	18124	2448	241	0	0	4210	2928	27951
1976	7714	2245	152	0	0	4133	2726	16970
1977	15492	1458	91	0	0	4979	3937	25957
1978	20059	2015	838	0	0	5390	2313	30615
1979	17291	2466	223	0	0	6053	3875	29908
1980	20068	2412	1435	0	0	5041	3706	32662
1981	19368	2610	187	0	0	4111	4504	30780
1982	19336	2906	80	0	0	4051	3390	29763
1983	18878	3237	11862	0	0	4986	2953	41916
1984	19862	3326	545	0	0	7026	2974	33733
1985	18613	3557	681	0	0	5369	2637	30857
1986	19329	3526	8263	0	0	5065	2391	38574
1987	19536	3589	760	0	0	3980	2394	30259
1988	18091	3738	420	0	0	4337	3615	30201
1989	19129	3371	740	0	0	5057	3821	32118

Source: Russ Rawson of the Los Angeles Department of Water and Power

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Table 9 – Historical Water Uses In The Owens Valley Study Area

Big Pine Area

WATER YEAR	IRRIGATION (AC-FT)	STOCKWATER (AC-FT)	OPERATIONS (AC-FT)	ENHCMT/MITIG (AC-FT)	GRNDWTR RECHG (AC-FT)	RECREATION (AC-FT)	INDIAN LANDS (AC-FT)	TOTAL (AC-FT)
1971	9623	2336	200	0	0	597	1721	14477
1972	9772	2876	320	0	0	436	1111	14515
1973	8224	2651	30	0	719	470	1041	13135
1974	8289	2331	0	0	1636	415	958	13629
1975	8390	1395	294	0	505	528	1012	12124
1976	4431	1781	115	0	0	446	1113	7886
1977	7962	1314	0	0	0	369	879	10524
1978	8517	1231	48	0	13746	345	547	24434
1979	7681	1501	0	0	8821	367	780	19150
1980	9044	1304	0	0	12798	371	635	24152
1981	8098	1577	0	0	3809	438	699	14621
1982	9004	1490	998	0	7566	586	695	20339
1983	7774	1378	902	0	18589	210	315	29168
1984	10525	1806	1574	0	2068	764	425	17162
1985	10780	1999	60	0	1210	741	497	15287
1986	9811	1609	3396	0	17090	853	443	33202
1987	10154	1436	5	3097	0	459	447	15598
1988	9758	1255	36	2384	0	966	573	14972
1989	10977	1551	37	2503	0	801	402	16271

Source: Russ Rawson of the Los Angeles Department of Water and Power

Table 9 – Historical Water Uses In The Owens Valley Study Area

Tinemaha To Haiwee Area

WATER YEAR	IRRIGATION (AC-FT)	STOCKWATER (AC-FT)	OPERATIONS (AC-FT)	ENHCMT/MITIG (AC-FT)	GRNDWTR RECHG (AC-FT)	RECREATION (AC-FT)	INDIAN LANDS (AC-FT)	TOTAL (AC-FT)
1971	6997	7336	1531	0	0	92	800	16756
1972	3548	3207	0	0	0	211	720	7686
1973	7409	4862	83	0	9155	45	246	21800
1974	7080	5460	1163	0	7046	131	1360	22240
1975	6084	4062	201	0	1729	120	829	13025
1976	3758	3846	1363	0	0	186	656	9809
1977	5479	2773	1115	0	0	160	644	10171
1978	9760	2977	931	0	27507	252	1132	42559
1979	7471	3378	1485	0	0	153	1121	13608
1980	7953	3892	620	0	54581	66	1281	68393
1981	6828	4195	992	0	0	121	1208	13344
1982	7857	4586	4333	0	15988	611	1562	34937
1983	6673	4223	4017	0	66765	562	1302	83542
1984	6298	5339	3092	0	0	814	1207	16750
1985	6149	5026	1104	58	0	330	1195	13862
1986	5592	4948	6661	804	54847	466	1260	74578
1987	4623	4607	445	4024	0	72	704	14475
1988	5781	4526	254	6265	0	77	861	17764
1989	5832	4278	573	8158	0	85	987	19913

Source: Russ Rawson of the Los Angeles Department of Water and Power

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Table 9 – Historical Water Uses In The Owens Valley Study Area

Overheads And Spillgates

WATER YEAR	IRRIGATION (AC-FT)	STOCKWATER (AC-FT)	OPERATIONS (AC-FT)	ENHCMT/MITIG (AC-FT)	GRNDWTR RECHG (AC-FT)	RECREATION (AC-FT)	INDIAN LANDS (AC-FT)	TOTAL (AC-FT)
1971	1027	3738	0	0	0	447	865	6077
1972	889	3887	0	0	0	615	930	6321
1973	870	3196	2203	0	0	344	910	7523
1974	1020	3398	1082	0	0	409	767	6676
1975	1164	2499	4243	0	0	1133	743	9782
1976	731	2788	1610	0	0	3297	956	9382
1977	1306	2306	2464	0	0	566	949	7591
1978	1050	2839	17449	0	0	1166	884	23388
1979	1120	3279	3760	0	0	1256	1011	10426
1980	761	2956	25085	0	0	2409	1025	32236
1981	1176	3263	6495	0	0	4518	1006	16458
1982	1285	3284	10944	0	0	4056	945	20514
1983	1241	3045	168189	0	0	1109	1038	174622
1984	1151	3643	32444	0	0	7522	989	45749
1985	1272	3162	5211	0	0	5982	1016	16643
1986	981	3248	54793	6732	0	4078	1164	70996
1987	1080	3708	342	16240	0	201	998	22569
1988	1125	3750	0	14498	0	420	1042	20835
1989	908	3524	2422	10040	0	1626	954	19474

Source: Russ Rawson of the Los Angeles Department of Water and Power

Table 10 – Calculated Groundwater Recharge In Acre-Feet For Water Years 1969 Through 1989

GROUNDWATER RECHARGE AREAS	WATER YEAR										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
McNally, South Of Upper #1	80	0	0	0	0	0	0	0	0	19	0
McNally, South Of Lower #1	80	0	0	0	0	0	0	0	0	19	0
Laws Ditch #1	40	0	0	0	0	0	0	0	0	9	0
McNally, South Of Upper #2	5130	0	0	0	0	1448	594	0	0	2351	404
McNally, South Of Lower #2	15390	0	0	0	0	4345	1783	0	0	7053	1211
Laws Ditch #2	5130	0	0	0	0	1448	594	0	0	2351	404
Wood Lot	0	0	0	0	0	0	0	0	0	0	0
Poleta Pasture Land	0	0	0	0	0	0	0	0	0	0	0
McNally Ponds	0	0	0	0	0	0	0	0	0	0	0
Lower McNally Extension	0	0	0	0	0	0	0	0	0	0	0
Farmer's Ponds #1	26	26	24	53	3	3	14	9	5	50	13
Kingsley Ponds	9	9	8	18	1	1	5	3	2	17	4
Arkansas Flats	17	17	16	35	2	2	10	6	4	34	9
Partridge Slough	17	17	16	35	2	2	10	6	4	34	9
Runkle Slough	17	17	16	35	2	2	10	6	4	34	9
Buckley Ponds	3010	3010	2166	2056	2202	3131	2947	2893	3485	3773	4237
Farmer's Ponds #2	0	0	0	0	0	0	0	0	0	0	0
Bishop Indian Reservation	953	953	868	971	1108	1055	878	818	1181	694	1163
East Of Crater Mountain	20	20	40	64	6	0	59	23	0	10	0
Crater Mountain Edge 1	3829	572	0	0	137	311	96	0	0	2612	1676
Crater Mountain Edge 2	1915	286	0	0	68	155	48	0	0	1306	838
Fish Springs	4978	744	0	0	178	404	125	0	0	3395	2179
Klondike Lake	0	0	0	0	0	0	0	0	0	0	0
Big Pine Indian Reservation	391	391	861	556	521	479	506	557	440	274	390
Blackrock/Thibaut Area 1	1810	0	0	0	0	0	0	0	0	609	0
Blackrock/Thibaut Area 2	1448	0	0	0	0	0	0	0	0	487	0
Blackrock/Thibaut Area 3	362	0	0	0	0	0	0	0	0	122	0
Independence Springfield	0	0	0	0	0	0	0	0	0	0	0
Independence Indian Reservation	456	348	240	216	74	408	249	197	193	340	336
Lone Pine Richards	0	0	0	0	0	0	0	0	0	0	0
Lone Pine Van Norman	0	0	0	0	0	0	0	0	0	0	0
Lone Pine Indian Reservation	285	285	260	279	273	230	223	287	285	265	303
VALLEY TOTAL	45393	6695	4515	4318	4577	13424	8151	4805	5603	25858	13185

Table 10 – Calculated Groundwater Recharge In Acre–Feet For Water Years 1969 Through 1989

GROUNDWATER RECHARGE AREAS	WATER YEAR									
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
McNally, South Of Upper #1	1	12	0	155	89	88	431	616	452	417
McNally, South Of Lower #1	1	12	0	155	89	88	431	616	452	417
Laws Ditch #1	0	6	0	77	44	44	215	308	226	208
McNally, South Of Upper #2	2690	389	2430	4613	36	0	3675	0	0	0
McNally, South Of Lower #2	8071	1168	7289	13840	107	0	11024	0	0	0
Laws Ditch #2	2690	389	2430	4613	36	0	3675	0	0	0
Wood Lot	0	0	4	24	86	41	26	32	63	30
Poleta Pasture Land	0	0	0	0	0	0	0	98	223	297
McNally Ponds	0	0	0	0	0	0	0	348	791	1057
Lower McNally Extension	0	0	0	0	0	0	0	98	223	297
Farmer's Ponds #1	86	11	5	712	33	41	496	46	25	44
Kingsley Ponds	29	4	2	237	11	14	165	15	8	15
Arkansas Flats	57	7	3	474	22	27	331	30	17	30
Partridge Slough	57	7	3	474	22	27	331	30	17	30
Runkle Slough	57	7	3	474	22	27	331	30	17	30
Buckley Ponds	3529	2878	2836	2338	3295	2518	2375	1867	2034	2372
Farmer's Ponds #2	0	0	0	1152	1623	1240	1170	919	1002	1168
Bishop Indian Reservation	1112	1351	1017	886	892	791	717	718	1085	1146
East Of Crater Mountain	0	0	200	180	315	12	679	1	7	7
Crater Mountain Edge 1	2432	724	1438	3532	393	230	3247	0	0	0
Crater Mountain Edge 2	1216	362	719	1766	196	115	1624	0	0	0
Fish Springs	3161	941	1869	4591	511	299	4221	0	0	0
Klondike Lake	0	0	0	0	0	0	0	929	715	751
Big Pine Indian Reservation	318	350	348	158	213	249	222	224	287	201
Blackrock/Thibaut Area 1	1053	0	428	1810	1676	0	1810	0	0	0
Blackrock/Thibaut Area 2	842	0	342	1448	1341	0	1448	0	0	0
Blackrock/Thibaut Area 3	211	0	86	362	335	0	362	0	0	0
Independence Springfield	0	0	0	0	0	8	106	531	827	1077
Independence Indian Reservation	384	362	469	391	362	359	378	211	258	296
Lone Pine Richards	0	0	0	0	0	3	43	217	338	441
Lone Pine Van Norman	0	0	0	0	0	3	43	217	338	441
Lone Pine Indian Reservation	308	302	284	311	297	305	349	299	313	286
VALLEY TOTAL	28305	9282	22205	44773	12046	6529	39925	8400	9718	11058

Table 11 - Recharge Source Components

Well Field Area	Streams	Ungaged Intermountain Slopes	Canals	Groundwater Recharge
Laws	Fish Slough Silver Creek Coldwater Creek Poleta	Chalfant - Fish Slough Fish Slough - Owens River Chalfant - Coldwater Coldwater - Silver Silver - Poleta	McNally Upper And Laws Ditch McNally Lower To Geiger Canal	McNally, South Of Upper #1 McNally, South Of Lower #1 Laws Ditch #1 McNally, South Of Upper #2 McNally, South Of Lower #2 Laws Ditch #2 Wood Lot Poleta Pasture Land McNally Ponds Lower McNally Extension
Bishop	Horton Creek McGee Creek Birch Creek (Near Bishop) Bishop Creek Rawson Creek Freeman Creek Shannon Creek Black Canyon	Owens River - Horton Horton - McGee McGee - Birch (Near Bishop) Birch (Near Bishop) - Bishop Bishop - Rawson Rawson - Freeman Freeman - Shannon Poleta - Black Canyon	A Drain A-1 Drain Bishop Creek Canal Bishop Creek, North Fork Bishop Creek, South Fork Bishop Creek Ditch C Drain Collins Canal Farmers Ditch To Duck Ponds Ford Rawson Ditch Geiger Canal Hall Ditch Indian Ditch Indian (South) To Newlan Ditch Owens River Canal (North) Owens RIver Canal (South) Rawson Canal Above Duck Ponds Rawson Canal Below Duck Ponds	Farmer's Ponds #1 Kingsley Ponds Arkansas Flats Partridge Slough Runkle Slough Buckley Ponds Farmer's Ponds #2 Indian Reservation
Big Pine	Baker Creek Big Pine Creek Birch Creek (Near Big Pine) Tinemaha, Red, Fuller Creek Westgard Pass Waucoba Canyon	Shannon - Baker Baker - Big Pine Big Pine - Crater Mountain (Front) Crater Mountain (Front) - Birch Birch - Fuller Fuller - Tinemaha Tinemaha - Red Mountain Black Canyon - Westgard Pass Westgard Pass - Waucoba Canyon Waucoba Canyon - Harkless Flats Harkless Flats - Papoose Flat Poverty Hills	Big Pine Canal Above Baker Creek Big Pine Canal Below Baker Creek	East Of Crater Mountain Crater Mountain, Edge 1 Crater Mountain, Edge 2 Fish Springs Klondike Lake Indian Reservation

Table 11 – Recharge Source Components

Well Field Area	Streams	Ungaged Intermountain Slopes	Canals	Groundwater Recharge
Taboose- Thibaut	Taboose Creek Goodale Creek Division Creek Sawmill Creek Thibaut Creek Oak Creek (Includes North Fork) (50%)	Red Mountain - Taboose Taboose - Goodale Goodale - Division Division - Sawmill Sawmill - Thibaut Thibaut - North Oak North Oak - South Oak (50%) Papoose Flat - Black Jack Mine Black Jack Mine - Mazourka Canyon	Spillgates - Owens River Intake Spillgates - Blackrock Spillgates - Thibaut	Blackrock/Thibaut Area 1 Blackrock/Thibaut Area 2 Blackrock/Thibaut Area 3
Independence- Symmes- Bairs	Oak Creek (Includes North Fork) (50%) Independence Creek Symmes Creek Shepherd Creek Bairs Creek (Includes North Fork) Georges Creek Hogback Creek Mazourka Canyon	North Oak - South Oak (50%) South Oak - Independence Independence - Symmes Symmes - Shepherd Shepherd - North Bairs North Bairs - Bairs Bairs - Georges Georges - Hogback Hogback - Lone Pine (50%) Mazourka Canyon - Reward Reward - Owenyo Owenyo - Long John Canyon Alabama Hills (NW Side) Alabama Hills (NE Side)	Spillgates - Independence Spillgates - Dean Spillgates - Russell Spillgates - Locust Spillgates - Georges	Independence Springfield Independence Indian Reservation
Lone Pine	Lone Pine Creek Tuttle Creek Diaz Creek Lubkin Creek (Includes North Fork)	Hogback - Lone Pine (50%) Lone Pine - Tuttle Tuttle - Diaz Diaz - North Lubkin Lubkin - Model Boundary Long John Canyon - Model Boundary Alabama Hills (SW Side) Alabama Hills (SE Side)	Spillgates - Diaz Spillgates - Lone Pine	Lone Pine Richards Lone Pine Van Norman Lone Pine Indian Reservation

Table 12 - Well Field Area Distribution of Underflow, Irrigation and Livestock, Precipitation, and Lake and Reservoir

WELL FIELD AREA	UNDERFLOW		IRRIGATION AND LIVESTOCK		PRECIPITATION		LAKE AND RESERVOIR	
	PERCENT OF TOTAL	RECHARGE (AC-FT)	PERCENT OF TOTAL	RECHARGE (AC-FT)	PERCENT OF TOTAL	RECHARGE (AC-FT)	PERCENT OF TOTAL	RECHARGE (AC-FT)
Laws	62.5	2500	10.0	1000	5.0	100	0.0	0
Bishop	37.5	1500	44.0	4400	15.0	300	20.0	200
Big Pine	0.0	0	22.0	2200	25.0	500	60.0	600
Taboose-Thibaut	0.0	0	10.0	1000	20.0	400	0.0	0
Independence-Symmes-Bairs	0.0	0	10.0	1000	25.0	500	0.0	0
Lone Pine	0.0	0	4.0	400	10.0	200	20.0	200
TOTAL	100.0	4000	100.0	10000	100.0	2000	100.0	1000

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Table 13 - Total Calculated Recharge In Acre-Feet For Water Year 1989

RECHARGE SOURCE	LAWS	BISHOP	BIG PINE	TABOOSE THIBAUT	INDEPENDENCE SYMMES BAIRS	LONE PINE	TOTAL
Streams	795	11916	8675	16196	18488	5308	61378
Ungaged I M S	315	2441	4196	3517	3412	1765	15646
Canals	5325	10864	2635	2014	1975	1951	24764
Groundwater	2723	4835	959	0	1373	1168	11058
Underflow	2500	1500	0	0	0	0	4000
Irrig And Livestock	1000	4400	2200	1000	1000	400	10000
Precipitation	100	300	500	400	500	200	2000
Lake And Reservoir	0	200	600	0	0	200	1000
TOTAL	12758	36456	19765	23127	26748	10992	129846

Table 14 – Summary Of Estimated Recharge And Historical Pumping In Acre–Feet For Water Years 1969 Through 1990

| WATER YEAR	LAWS RECHARGE	LAWS PUMPING	BISHOP RECHARGE	BISHOP PUMPING	BIG PINE RECHARGE	BIG PINE PUMPING	TABOOSE-THIBAUT RECHARGE	TABOOSE-THIBAUT PUMPING	IND-SYM-BAIRS RECHARGE	IND-SYM-BAIRS PUMPING	LONE PINE RECHARGE	LONE PINE PUMPING	OWENS VALLEY RECHARGE	OWENS VALLEY PUMPING
1969	38281	0	73212	0	56899	534	69211	3501	71340	662	24477	1260	333420	5957
1970	10671	2616	42589	0	27968	2219	35405	2546	37472	2929	13487	2154	167592	12464
1971	10307	21020	37129	0	22768	26715	28329	21482	30854	23852	12092	2014	141479	95083
1972	10125	28541	34954	2363	20445	41621	25218	48158	27348	39814	10980	2357	129070	162854
1973	10797	22510	43442	7593	28293	21493	36732	39503	40085	31596	15166	2364	174515	125059
1974	18057	8528	44545	1516	28935	13009	37043	28239	40767	18678	15236	2350	184583	72320
1975	13441	8982	39925	2415	24539	32314	31130	40240	33994	16299	13076	1958	156105	102208
1976	10035	15138	34363	4867	19386	28566	23660	53114	25588	29641	10421	2167	123453	133493
1977	9871	15661	33271	11281	17404	29603	20861	44712	22451	23190	9397	2103	113255	126550
1978	23108	7773	53632	2758	40699	34355	46662	33383	50097	23572	18331	2685	232529	104526
1979	12671	6533	43755	5420	30831	25796	34243	15030	37563	3782	14290	2038	173353	58599
1980	24904	12511	55734	2364	41863	26614	50041	28047	52926	14297	19281	1762	244749	85595
1981	12463	12338	41540	6919	26286	27211	31438	21354	34455	4702	13267	1673	159449	74197
1982	23622	14525	54899	6271	39514	24302	49103	26429	53359	8054	19370	1306	239867	80887
1983	35781	1038	70019	11	54564	25543	66183	14433	69294	318	24609	1250	320450	42593
1984	11758	6854	54463	3773	34320	27154	48176	13691	49425	367	18137	1772	216279	53611
1985	10913	10016	43995	9777	26653	26937	34243	27460	37594	8788	14298	2197	167696	85175
1986	31217	9953	60341	1809	47994	25054	56535	27325	58596	7842	21221	2439	275904	74422
1987	12405	21220	38443	9558	22816	38946	29544	53314	30067	32542	12193	1660	145468	157240
1988	12538	22486	36729	10900	20631	33667	25907	55195	27169	40348	11297	1389	134271	163985
1989	12758	38167	36456	11961	19765	35915	23127	54284	26748	34728	10992	1668	129846	176723
1990 (a)	10437	11850	31891	2300	16478	16200	20630	16050	22942	11200	9655	400	112033	58000
WY 70-89														
TOTAL	317442	286410	900224	101556	595674	547034	733580	647939	785852	365339	297141	39306	3629913	1987584
AVERAGE	15872	14321	45011	5078	29784	27352	36679	32397	39293	18267	14857	1965	181496	99379
WY 71-90														
TOTAL (b)	317208	295644	889526	103856	584184	561015	718805	661443	771322	373610	293309	37552	3574354	2033120
ESTIMATED APR-SEP 1990 PUMPING LIMIT		21564	(c)	785670		23169		57362		397712		255757		1541234

(a) Estimated Recharge for 1990 Water Year; Approximated Pumping for First Half of Water Year 1990 (Oct-Mar)

(b) Estimated 20 Year Total for Recharge and Estimated 19.5 Year Total for Pumping

(c) Bishop Cone Pumping Actually Limited to No Greater Than the Total Amount of Water Used on Los Angeles-Owned Land on the Cone

FIGURE 1 LAWS WELL FIELD AREA RECHARGE

RECHARGE = 455 + 0.976*RO**2 • 387536/RO
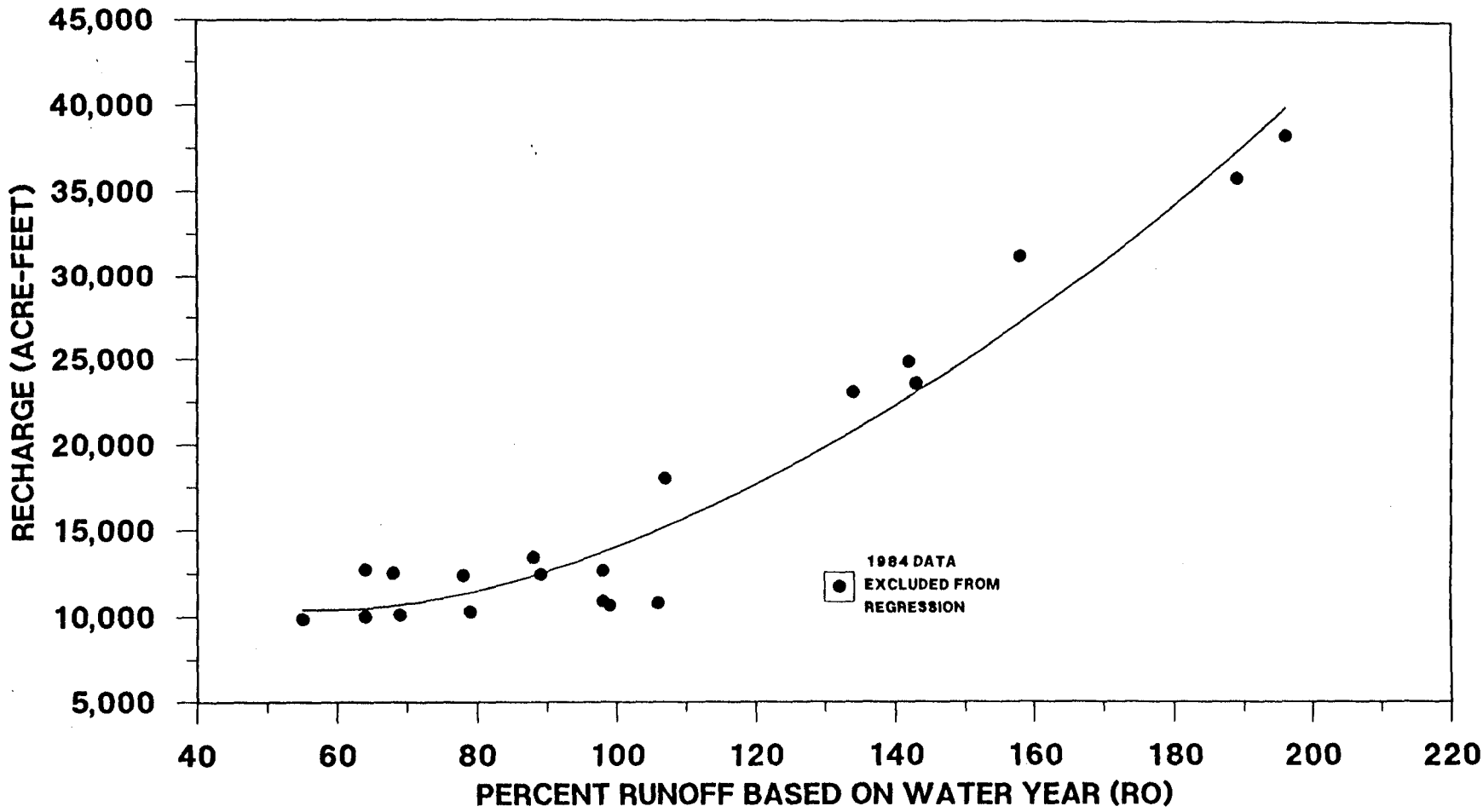
WATER YEARS 1969 THROUGH 1989
I**2 = 0.942
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)

FIGURE 2 BISHOP WELL FIELD AREA RECHARGE

RECHARGE = 281*RO + 16,144

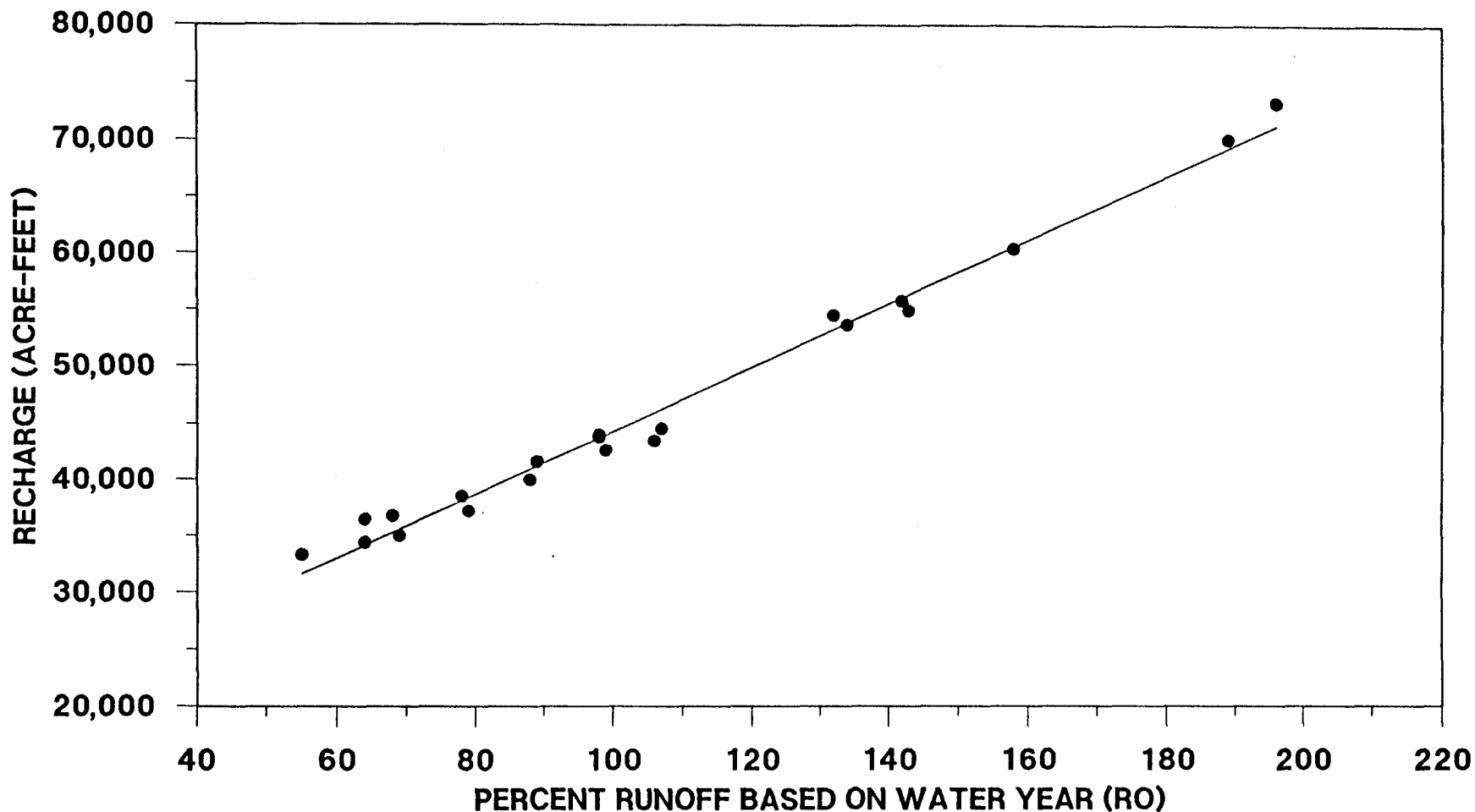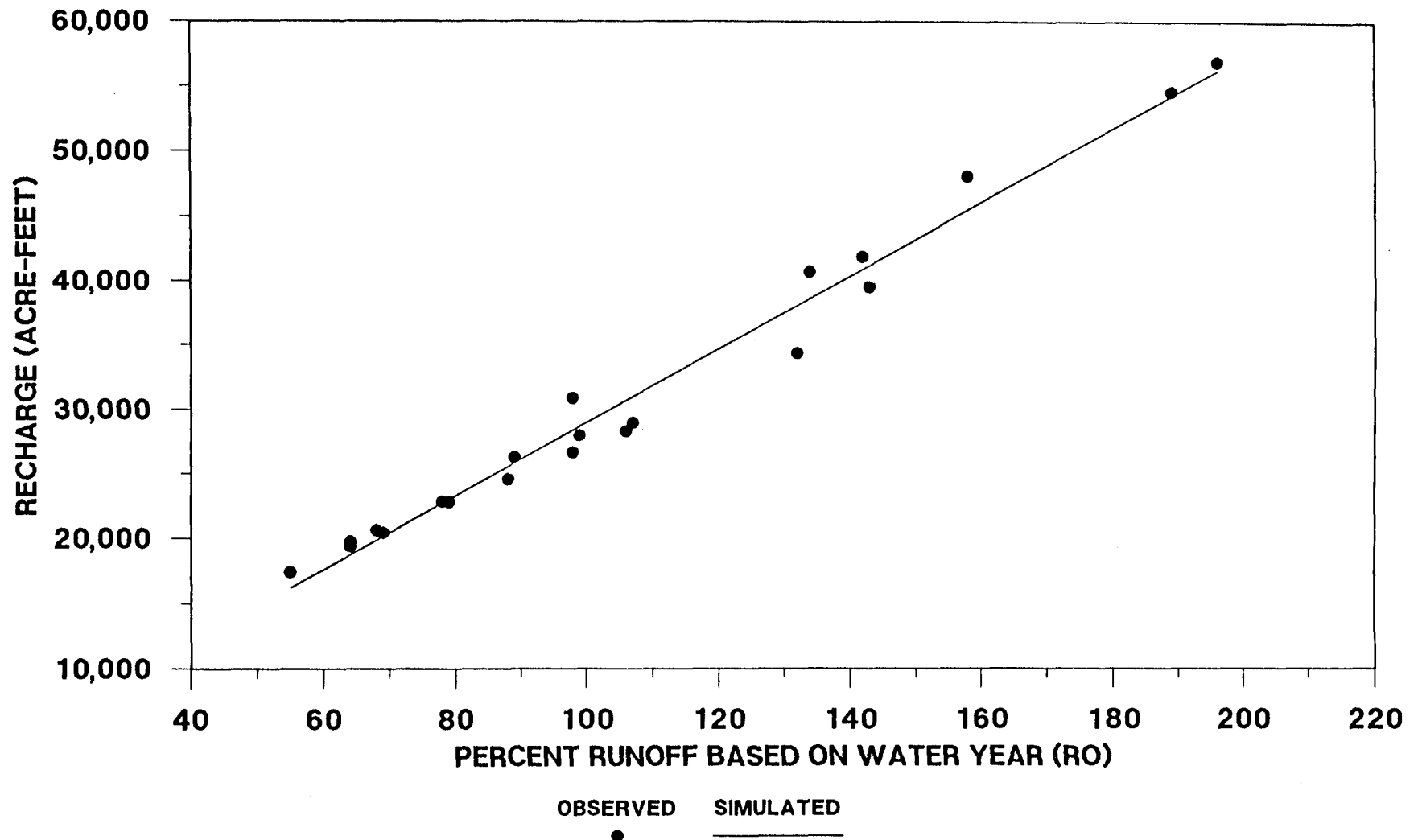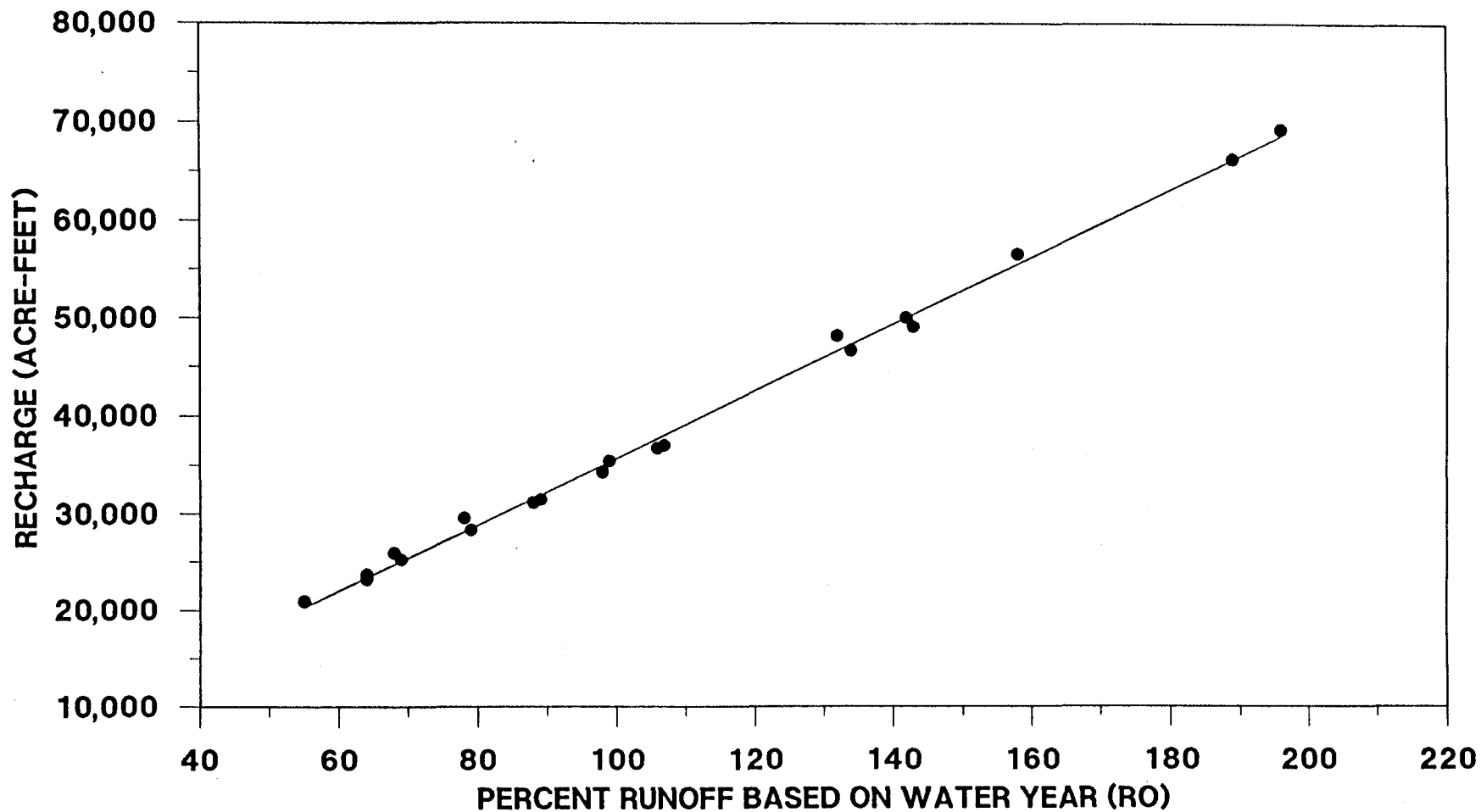

OBSERVED   SIMULATED

WATER YEARS 1969 THROUGH 1989
R**2 = 0.986
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)

FIGURE 3 BIG PINE WELL FIELD AREA RECHARGE

RECHARGE = 284*RO + 584

OBSERVED   SIMULATED

WATER YEARS 1969 THROUGH 1989
R**2 = 0.982
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)

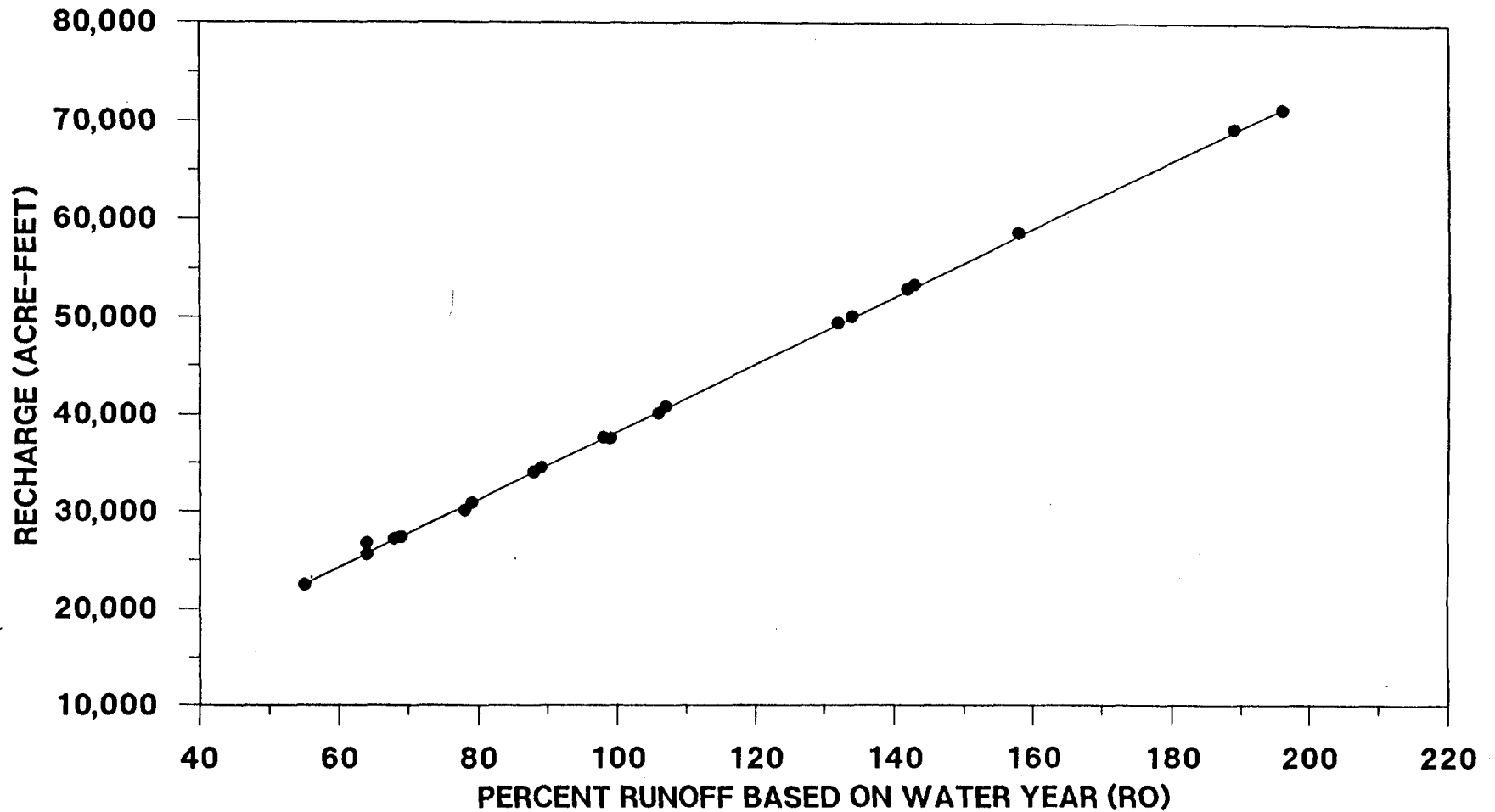# FIGURE 4 TT WELL FIELD AREA RECHARGE

RECHARGE = 342*RO + 1,466

WATER YEARS 1969 THROUGH 1989
R**2 = 0.995
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)

FIGURE 5 ISB WELL FIELD AREA RECHARGE
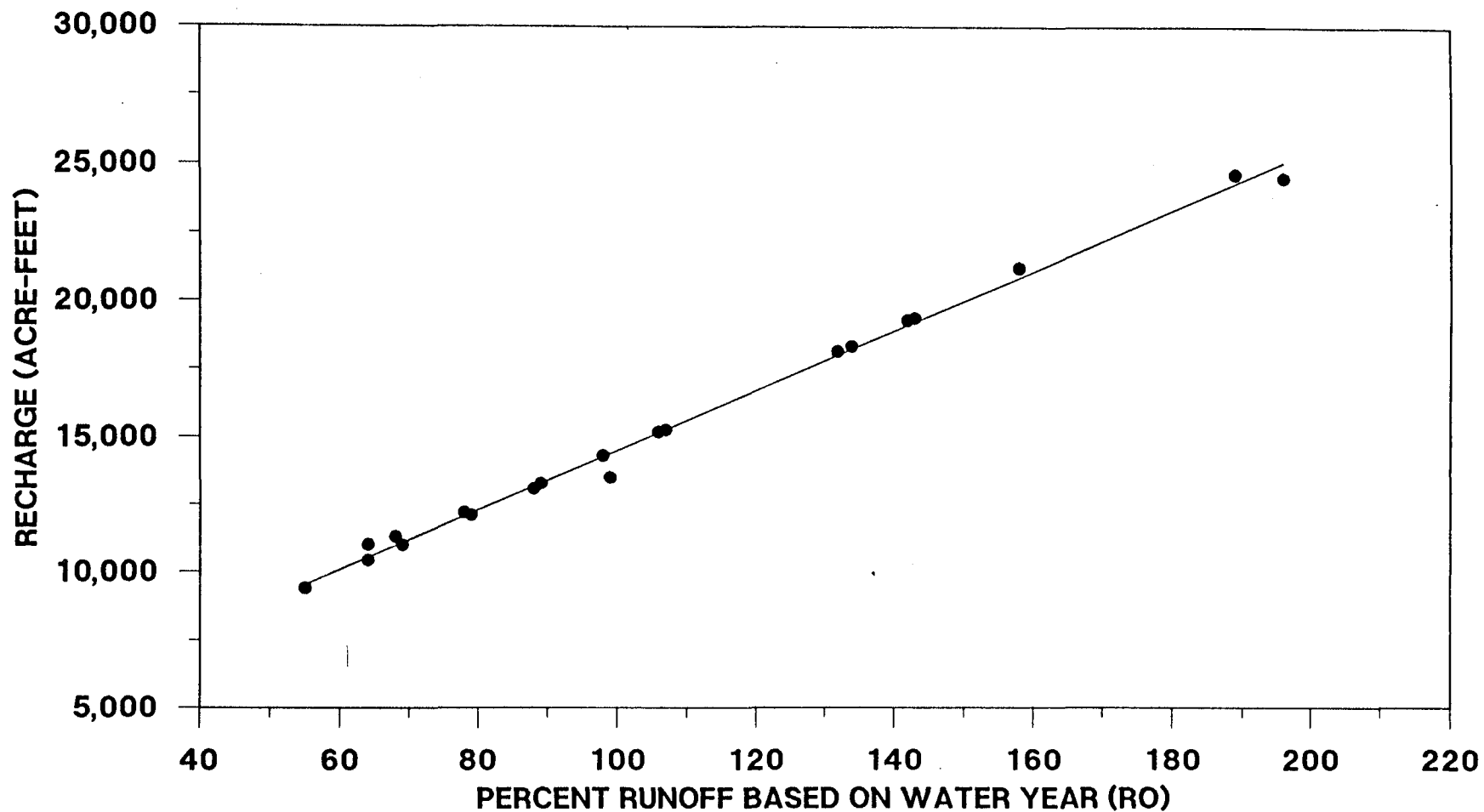
RECHARGE = 347*RO + 3,475

OBSERVED   SIMULATED

●

WATER YEARS 1969 THROUGH 1989
R**2 = 0.996
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)

FIGURE 6 LONE PINE WELL FIELD AREA RECHARGE

RECHARGE = 110*RO + 3,492

OBSERVED   SIMULATED

WATER YEARS 1969 THROUGH 1989
R**2 = 0.994
AVERAGE RUNOFF = 469,852 AC-FT (WY 1935-1984)